Re-developing knowledge creation capability: Innovating in Indian pharmaceutical industry under the TRIPS regime

Thesis

Re- developing knowledge creation capability: Innovating in Indian pharmaceutical industry under the TRIPS regime

Dinar Kale

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Walton Hall

Milton Keynes,

MK7 6AA

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Summary

The transition to a new technology, market or regulatory regime can be difficult for any organisation to manage. Technological and institutional change has proven to be a big cause for the failure of established firms and many examples exist of such failures. The Trade Related intellectual property rights agreement (TRIPs), as part of The World Trade Organization (WTO) agreement, represents such an institutional change for knowledge based industries from developing countries. As a result of the TRIPs agreement all of the WTO member countries will move from no or partial patent protection to fully fledged patent protection. This represents a radical break with the past in which developing countries typically had only weak levels of patent protection. Against this backdrop, the research examines the learning processes involved in the development of innovative R&D capabilities within the context of the Indian pharmaceutical industry, in response to the strengthening of patent law.

In the last decade much research has addressed the process of dynamic learning within firms, however this has predominantly focused on firms from advanced countries. Previous research on developing countries mainly focused on building the minimum knowledge base essential for production and innovation activity. In recent years limited research has begun to explore dynamic learning in firms from developing countries. However, there still remains a scarcity of research which examines firm-level learning processes central to the development of advanced level capabilities. This research addresses this deficiency by applying the conceptual understanding developed within advanced countries to a developing countries context. This is operationalised through a set of research activities which investigate firm-level learning, knowledge creation and innovative capability within the context of the Indian pharmaceutical industry.

The substantive conclusions are that the development of new capabilities involves the removal of redundant capabilities, coupled with the acquisition of new knowledge. The findings also indicate that Indian firms are hiring Indian scientists educated or working overseas in multinational pharmaceutical R&D and collaborating with Indian and overseas research institutes and universities to acquire capabilities in innovative R&D. Furthermore, inter-firm differences in learning processes suggest that at a firm level, learning is neither linear nor automatic and requires a deliberate strategy. The thesis also provides important insights into knowledge creation capabilities that have significant implications with respect to innovative activity for firms from other developing countries.

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Chapter 1

INTRODUCTION

1.1 The issues addressed

The transition to new technology, science, market or regulatory regime is difficult for any organisation, public or private to manage. The discontinuities forcing these transitions are mostly driven by technology, competitors, regulatory events or significant changes in economic and political conditions. Even when established firms recognise the need to change in response to shifts in their external environment, they are often unable to respond. Technological change and institutional change have proven to be big causes for the failure of established firms and history is full of such examples (Tushman and Anderson, 1986; Henderson and Clark, 1990; Utterback, 1994; Christensen, 1997). With the advent of globalisation the pace of these transformations appears to be accelerating and the resulting pressure to change is mounting. Therefore in recent years the ability and efforts of firm, enterprise or countries to develop appropriate understanding and response to change by transforming capabilities has become one of the central areas of research in management science.

In the globalised era, the ability of firms to renew or reconfigure existing competencies and create new knowledge for innovation has emerged as a strategically important capability (Dosi, 1988; Pavitt, 1991, Teece et al., 1997). Several firm level empirical studies of renewal or reconfigurations of capabilities involving mechanisms of learning and knowledge creation have emerged during the past two decades. Some of these studies have drawn on the traditional 'organisational learning' literature (e.g. Simon, 1991; Hedberg, 1981; Levitt and March, 1988). These studies argue that knowledge is the foundation of capability and source of performance differences among firms in their industry (see for instance, Nonaka and Takeuchi, 1995; Leonard – Barton, 1995; Kogut and Zander, 1992; Teece et al., 1997; Henderson and Clark, 1990). This literature mainly concentrating on firms from advanced countries competing at the technology frontiers, addresses the firm's capabilities – and knowledge creation in industrialised economies with reference to maintaining and renewing strategic innovative capabilities that already exist (e.g. Cohen and Levinthal,1990; Prahalad and Hamel,1990; Kogut and Zander,1992; Nonaka and Takeuchi,1995; Spender, 1996a). However this body of literature pays little attention to how those capabilities or knowledge bases were initially accumulated.

In the case of firms from developing countries, transformation of capabilities differs in complexity compare to firms in advanced countries as in developing countries economic, political and social complexities makes the transformation of capabilities a challenging and difficult process.

In the past the literature focused on developing countries has mainly addressed process of capability accumulation in firms and industries (see for instance Dahlman and Westphal, 1982; Bell and Pavitt, 1995; Lall, 1987, 1992; Katz, 1987; Hobday, 1995). Most of these studies have been based on long-term descriptions of capability accumulation in industries from developing countries. This tradition has concentrated on the learning process involved in building essential minimum knowledge base to engage in innovation activity. Therefore, these studies have not yet paid enough attention to the capability transformation or capability renewal in developing countries firms. Also despite the emergence of more comprehensive firm level studies during the mid -1990s (eg. Kim, 1997a; Dutré nit, 2000; Figueiredo, 2003) comparative analysis of learning and capability accumulation in firms from developing countries or newly industrialising countries has still been absent in this research stream.

This research takes up that task. This research explores the learning processes involved in the transformation of capabilities to develop new competencies by firms from developing country as a response to change in regularity environment. More specifically this research investigates approaches used by the Indian pharmaceutical firms to move from imitative R&D competencies to innovative R&D competencies as response to the change in patent law. The focus of the research is firm level learning processes involved in reconfiguration or renewal of capabilities for innovation and inter firm differences in learning processes. It also covers the long term process of capability accumulation at industry and firm level.

The impact of the Trade Related Intellectual Property Rights (TRIPS) agreement as part of the World Trade Organisation (W.T.O.) agreements on pharmaceutical industry in developing countries forms the genesis of this research. TRIPS is instrumental in setting uniform standards of intellectual property all over the world and as a result large part of the world is moving from partial or no patent protection to the full fledged patent protection. Pharmaceutical industries based in developing countries have built basic capabilities through imitative R&D and which will be restricted as a result of strengthening of patent law. As a result pharmaceutical firms in developing countries have to undergo discontinuous learning for transforming existing capabilities and developing of new competencies to survive and grow in emerging competitive environment. The extensive literature that deals with the change in patent law and its impact on various healthcare

issues has not paid enough attention to the strategic capability transformation by pharmaceutical firms from developing countries as a response to the changed patent law.
The empirical evidence for this research comes from a study of the innovative firms in the Indian pharmaceutical industry. The choice of India provides the ideal setting for this research as the Indian pharmaceutical industry is one of the success stories of self reliant imitation based development in the developing world.

1.2 Research context and question

World trade agreements, especially TRIPS agreements, are setting new 'rules of the game' by harmonising the intellectual property rights (IPRs) all over the world. Now due to TRIPS agreements for the first time in international law, all countries are required to provide protection to both process and product inventions made in all fields of technology, subject to classical parameters of novelty, non-obviousness and usefulness. In the case of pharmaceuticals and agro chemicals, patents will now be granted both for products and processes for the inventions in all fields of technology; the patent term will be twenty years from the date of application. In the case of a dispute on infringement, the responsibility of proving innocence lies with the accused, rather than the patent holder proving infringement of the accused. This broad regulatory framework will now guide and control the pharmaceutical industry in WTO member countries.

The strength of the patent regime plays an important role in knowledge intensive industries and especially in the pharmaceutical industry. In the pharmaceutical industry, patents provide strong appropriation and profit maximisation by conferring limited monopoly rights to inventors. As a result the strength of an IPR regime is a strategically important issue for pharmaceutical firms but sensitive for countries. The degree of patent protection given to pharmaceutical products in the past was clearly related to the development of the domestic pharmaceutical industry. In some developing countries like India and China the absence of product protection allowed the non market mediated mechanisms like reverse engineering or imitative R&D and thus played a crucial role in the development of the domestic pharmaceutical industry. But now due to the strengthening of patent law, these activities will be restricted and that will severely affect industrial growth (Watal And Mathai, 1995). Thus TRIPs agreement represents a substantial and complex challenge for pharmaceutical firms in developing countries.

Numbers of studies have been carried out on the effect of change in patent law on drug related healthcare issues in developing countries. These include studies focusing on socio economic issues like the pricing of the drugs (see for instance, Lanjouw, 1996; Watal, 2000; Nogues,1993), technological development of the firms (e.g. Sequeria, 1998) and the

resultant heterogeneity (D'Este, 2002) as well as strategic issues like adaptive strategies of firms as a response to change (Madanmohan and Krishnan, 2003; Halemane and Dongen, 2003). Most of the research on effect of TRIPS agreement has focused on welfare issues like prices of drug and strategic issues like its implications for technological development, foreign direct investment. But very few studies have explored how the pharmaceutical firms in developing countries are responding to changes in patent law or how these firms are overcoming the organisational and managerial challenges associated with transformation of firm capabilities in their responses to change in patent laws.

This research examines these questions by studying the innovative firms in Indian pharmaceutical industry and so Indian pharmaceutical industry is focus of this research. Some of the firms from Indian pharmaceutical industry have responded to TRIPS challenge by building capabilities for innovation and therefore these firms provides ideal set up to explore questions raised by TRIPS. There are two important challenges for Indian pharmaceutical firms in development of competence for innovative R&D. The first important challenge for Indian firms is financial and infrastructure requirements for innovative R&D. The innovative research and development is a very costly and risky process, it takes up to 8-10 years and 500 -600 US$ million (Appendix I). However the bigger and more complex challenge is of knowledge bases and capabilities; the knowledge base and capabilities required for innovative R&D and reverse engineering R&D differs a lot.

So it raises the question:

- **How are Indian pharmaceutical firms building strategic knowledge creation capability for innovation as a response to change in regulations?**
- **How relevant is knowledge accumulated through imitation for firms in their efforts to create innovative novel products?**

1.3 The case study: The Indian pharmaceutical industry

The Indian pharmaceutical industry has shown remarkable growth in recent years and it is now respected in the world as 'wonder of the third world'. The pharmaceutical industry in India is comprised of public and private sector units in organised sector and small scale units in the unorganised sector. It represents a successful high technology based industry, which has witnessed consistent growth over the last three decades. Its total worth in 2003 was US $ 6.5 billion and in last decade, it has consistently grown at 8-10 % in a year. It's

fourth largest pharmaceutical industry in terms of volumes and 13th largest in terms of market value. The Indian pharmaceutical industry is now counted among top five manufacturers of bulk drugs.

The weakening of patent law in 1972 played a key role in growth and development of the Indian pharmaceutical industry. From 1970 onwards Indian pharmaceutical firms slowly started dominating the domestic market reducing the market share and influence of Western companies. Today the market share of Indian firms in domestic market is around 60-70% compared to 10% in 1970 (Ramani, 2002). The Indian pharmaceutical industry has developed enough capabilities to make the country self sufficient in its health care needs. Of the 550 bulk drugs which are formulated in the country, about 350 drugs are manufactured indigenously.

In recent years it has emerged as one of the major suppliers of cheap drugs to developing as well as advanced countries. Now Indian pharmaceutical industry exports generic drugs not only to the developing or emerging regions like South East Asia, CIS (Commonwealth of Independent States) countries, Africa, but also to the highly regulated US and European markets. In 2003 Indian pharmaceutical exports were worth $2billion and have increased consistently over the last decade making it a strategic trade sector in the Indian economy.

During the last three decades, the large private Indian pharmaceutical firms focused their efforts on reverse engineering oriented process R&D, and activity was limited to applying known knowledge, or to making small adjustments in the contents (Wendt, 2000). A few government owned laboratories under the Council of Scientific and Industrial Research (CSIR) also operated in pharmaceutical R&D, specifically focusing on the 'indigenisation' of technology. The intensive efforts of Indian pharmaceutical firms has resulted in extensive expertise regarding production technologies and process R&D and the lag period between the launch of a new product in its first market and India was thus reduced, in some cases as low as two years (Lanjouw, 1996). As a result Indian pharmaceutical firms have accumulated extensive knowledge in process R&D (synthetic and organic chemistry). In recent years Indian firms have developed some of the most innovative processes for drug production.

However with the signing of WTO agreements, specifically TRIPS in 1994, the Indian industry and market structure is poised to change. In a product patent regime, Indian firms will have to look for new sources of growth and in the emerging competitive scenario the biggest source will be productive R&D, which can deliver patentable innovations. Some Indian pharmaceutical firms have shown early success in innovative R&D and this research explores how these firms are transforming existing capabilities to achieve success in innovative R&D.

1.4 Theoretical Framework

The theoretical framework used for analysis is based on the concepts from organisational learning, knowledge based theory of the firm and innovation management literature. In a rapidly changing globalising world, the challenge for firms is to find new ways of doing things (Teece, 2000). In the management literature there is increasing evidence that knowledge allows the creation of the capability and that determines the ability to do things (Grant, 1991; Henderson and Cockburn, 1994; Leonard- Barton, 1995). The manner of knowing or learning is as important as what should be known (Spender and Grant, 1996). Leonard – Barton (1992) points out that the firm nurtures and creates knowledge through certain activities and these activities basically involve the sharing of knowledge within the organisation, and the transfer and integration of knowledge across organisational boundaries. However in the case of technological advances or fundamental regulatory reforms firms have to develop new competencies through revolutionary change or discontinuous learning (Tushman and O'Reilly III, 1996). The capability of the firm to maintain, nurture and renew or reconfigure technological capabilities is based on the ability of the firm to develop new competencies by acquiring new knowledge and integrating or combining it with existing knowledge bases (Kogut and Zander, 1992, Teece, et al., 1997; Cohen and Levinthal, 1990). In a similar vein Henderson and Clark, (1990) suggest that such change and adoption involves not only learning new components of knowledge but also the new linkages between the components and so it requires reconfiguration of existing systems of linkages in new way. Therefore in such uncertain environment firms' ability to change and adopt depends upon the absorptive capacity which is defined as ability to evaluate, assimilate and apply outside knowledge (Cohen and Levinthal, 1990). Absorptive capacity is viewed as a function of two separate but interrelated dimensions:

a. the firm's ability to acquire the knowledge relevant to the new technological paradigm

b. firm's ability to integrate external knowledge into existing capabilities.

The theoretical framework broadly focuses on practices or mechanisms associated with these two dimensions of absorptive capacity. Therefore it explores the processes involved in acquisition, transfer, assimilation and application of new knowledge. It also explores the relevance of prior knowledge in terms of its nature, its usefulness in innovative R&D and the processes involved in building the prior knowledge base.

Large pharmaceutical firms' transformation of capabilities as a response to biotechnological challenge helps in activating the framework. The emergence of biotechnological change and responses to large pharmaceutical firms provides better understanding of mechanisms used by incumbent firms to transform its capabilities in face

of an external technological discontinuity. It specifically illustrates the specific mechanisms involved in development of new competencies through discontinuous learning. In this research these mechanisms used as a guide to explore the transformation of capabilities in Indian pharmaceutical firms.

1.5 Research Methodology

The empirical part of the thesis will draw from data collected through range of quantitative and qualitative methods. This research is focused on exploring processes involved development of capabilities in Indian pharmaceutical firms. So qualitative research methodology forms the main basis of research strategy and interviews as the principle mechanism of data collection. It is quite evident from different researchers' approaches to studies of capability development that qualitative methodology certainly helps to capture the richness and complexities of the issues at hand (Hoskisson et al., 1999).

Research was carried in two phases; the first phase involved qualitative interviews with pharmaceutical consultants, patent experts and presidents of Indian pharmaceutical associations. Along with interviews, an electronic survey was also carried out to explore effects of change in patent law on the Indian pharmaceutical industry. The survey was sent electronically to scientists/researchers working in Indian pharmaceutical firms, universities and supporting research institutions. The interview questions and survey questionnaire used for the first phase was mainly focused on industry level issues such as the effect of changes in patent law on industry structure, market structure and emerging challenges.

In the second phase research is focussed on firm level analysis as the micro level analysis can provide better understanding of the processes involved in transformation of existing capabilities and development of new competencies. According to Pavitt (1991) firms are key actors in the process of technology capability development as the technological change is basically localised in the firms. Therefore in the second phase a case study methodology (Yin, 1994) was chosen to examine the firm level learning processes involved in the knowledge accumulation and development of new competencies. The Indian pharmaceutical firms who have made transformations from imitative R&D to innovative R&D are selected to study in this research. The multiple case study design was used and the cases were chosen on the basis of degree of innovativeness and strategies to transform themselves. But only those firms were selected for the study which has filed patent for new chemical entities in India as well as in US.

The interviews were transcribed and analysed by using techniques like pattern matching (Yin, 1994) and systematic building of analytical tables (Miles and Huberman, 1984). The

different patterns were identified and categorised using Atlas.Ti data analysis software. The interview transcripts were analysed by locating series of narratives around the transformation issues in each firm and from these, replicating patterns of acquisition and transformation processes were identified. These patterns were supplemented by secondary data which was collected from industry journals, industry association publications and annual reports of firms. The observed patterns in Indian pharmaceutical firms were then compared with the theoretical patterns identified from the framework to find the similarities and differences between them. The results of analysis were sent to key members of each researched firm and their feedback was included in the final results.

1.6 Principle findings

1.6.1 Firm level processes involved in development of knowledge capability for innovation

This research shows that development of new capabilities involved removal of capabilities which were redundant in new era, acquisition of new knowledge and combination of new knowledge with existing relevant capabilities. The analysis revealed that in case of Indian pharmaceutical firms the main rigidities that emerged are a. imitative R&D organisational routines, b. in-house nature of R&D and c. organisational mindset shaped by short term vision of R&D investments and domestic market approach.

In the case of Indian pharmaceutical firms networked model of collaborative R&D and learning by hiring has emerged as the main mechanisms of knowledge acquisition. These firms created linkages with Indian as well as international research institutes to fill the knowledge gaps and train its scientific workforce. The Indian pharmaceutical firms hired product R&D experienced scientists working overseas in MNC pharmaceutical R&D firms or universities to acquire the know-how in innovative product R&D. The hiring of foreign educated or experienced scientists helped Indian firms to fill knowledge gaps in areas of innovative R&D and acquire crucial tacit knowledge. In the case of Indian pharmaceutical firms the presence of diaspora in terms of Indian scientists community in advanced countries emerged as an important resource of knowledge in the advanced areas of innovative R&D.

The analysis points out that the Indian pharmaceutical firms set up various organisational arrangements like adoption of matrix form of project management to encourage the sharing of knowledge among its R&D scientists. These mechanisms helped Indian pharmaceutical firms to create an environment that facilitated the assimilation of new knowledge among its scientific workforce.

The analysis also shows a strong emphasis on the integration of different knowledge bases across all firms. In the case of Indian pharmaceutical firms cross disciplinary teams and frequent scheduled as well as ad hoc project meetings played a critical role in achieving the integration of different knowledge bases.

This research points out that learning process adopted by the Indian pharmaceutical firms shared similarities with the large multinational firms' approaches to transform their technological identity as a response to molecular biology advances. This suggests that as far as intra firm learning is concerned learning processes followed by technology frontier firms are also applicable to firms from developing countries. However firms in developing countries have to modify learning strategies according to their institutional environment.

1.6.2 Movement from imitators to innovators: neither linear nor automatic

The inter firm comparative analysis reveals subtle differences in functioning and implementation of learning processes in each firm showing that learning at firm level is neither automatic nor linear and requires a deliberate learning strategy. For example, in case of learning by hiring, the nature of scientists targeted for recruitment as well as sourced used by firms for recruiting new scientists differs a lot. Similarly inter firm differences emerged in supportive learning mechanisms that encourages interaction among distributed knowledge systems. The learning mechanisms like incentive policies, top management commitment and emphasis on collaboration and networking differed across the firms. This influenced the creation of environment that facilitates the development of collective knowledge. Therefore it emerges that movement of a firm from imitative R&D to innovative R&D is neither linear nor automatic and requires an intensive effort from firms to invest in different mechanisms of learning.

The inter firm differences in implementation and functioning of learning processes also suggest that firm engaged in different modes of learning as they respond to external conditions. These differences have profound effects on the movement of firms from imitative R&D to innovative R&D and emerged as one of the main reason for differences in innovative R&D capabilities among the firms under study. Therefore this finding support the observation by Figueiredo (2002) that the way in which intra firm learning processes and mechanisms managed over time plays a substantial part in influencing inter firm differences in terms of technological capability and, in turn, the competitive performance.

1.6.3 Technological capability accumulation process in Indian pharmaceutical industry and TRIPs

The Indian pharmaceutical industry's journey from being an import depended industry to becoming a global supplier of pharmaceuticals has been long and eventful one. This research presents a model of dynamic learning processes involved in technology capability development in Indian pharmaceutical industry. It shows that industry has followed the trajectory of starting with duplicative imitation followed by creative imitation to rise up the value chain of pharmaceutical R&D and finally as a result of change in patent law industry is undergoing learning to develop capabilities in innovative R&D.

The analysis reveals that strengthening of patent laws as a result of TRIPs agreement had a positive impact on large Indian pharmaceutical firms and catalysed their movement from imitators to innovators. It played an important role in creating 'crisis for their existence' and that triggered their movement towards the innovative R&D competencies. However it also emerged that imitative R&D in these firms created important essential basic capabilities and that acted as a base for innovative R&D. The basic and intermediate technological capabilities learnt as a result of imitative learning certainly gave these firms a solid base for development of competence in advanced innovative R&D. This certainly raises the question about linking patent laws to trade policy as evident in the WTO and not to capabilities of domestic pharmaceutical industry.

This research also shows that strengthening of patent law changed the strategic orientation of Indian pharmaceutical industry and forced Indian firms to pursue the alternative technological innovative trajectories. These Indian pharmaceutical firms responded to strengthening of patent law by adopting ambidextrous technology capability development paths in form of innovative process and product R&D. The Indian firms are competing in advance countries generic markets and supplying active pharmaceutical ingredients to large MNC pharmaceutical firms, and in parallel to that these firms are also developing new chemical entities and new drug delivery systems. Therefore these Indian firms transformed their capabilities ambidextrously; on one side by incrementally improving the basic capabilities by competing in generics market and supplying drugs to MNC, while at the same time these firms developed capabilities in innovative R&D which represents a radical change. This finding has important implication for pharmaceutical firms in other developing countries which will be facing similar challenges due to TRIPS agreement. Pharmaceutical firms in other developing countries can adopt similar approach in their responses to regularity discontinuities.

1.7 Structure of the thesis

This section describes the organisation and content of all the chapters in the thesis. Figure 1.1 depicts the flow of the chapters in our thesis.

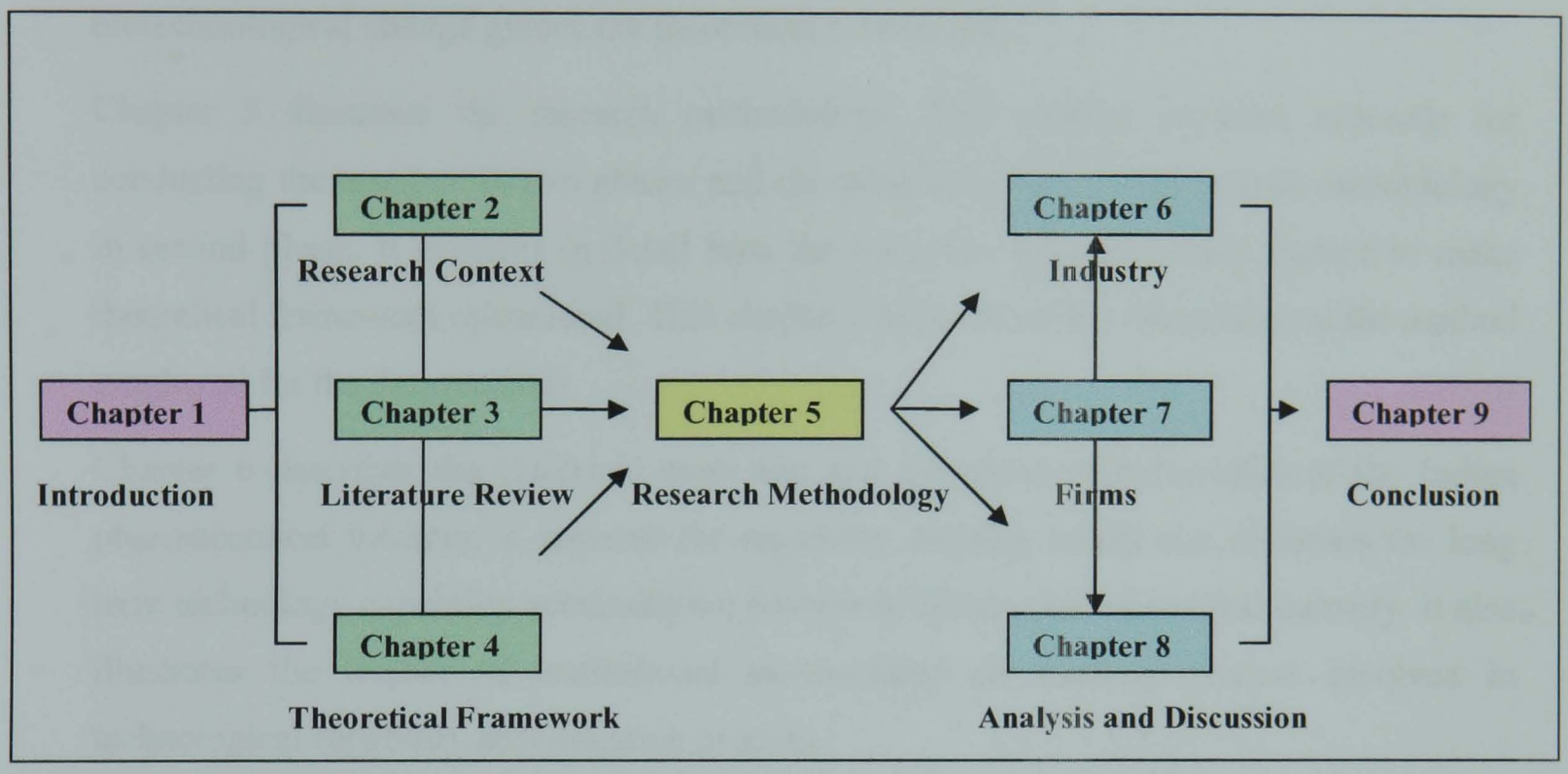

Figure 1.1 The thesis organisation

This dissertation consists of nine chapters, including this introductory chapter. The content of the subsequent chapters are briefly described below.

Chapter 2 provides the general overview of the research context. It focuses on the genesis of the research; the Trade Related Intellectual Property Rights (TRIPS) agreement and its impact on the knowledge based industries in developing countries. It also briefly discuses the relevant literature on various patent related issues such as evolution of patent system in advanced and developing countries and its impact. In the concluding section this chapter introduces the characteristics of Indian pharmaceutical industry which is the main focus of this research.

Chapter 3 reviews the literature on the technology capability development in relation to firms from developing countries and advanced countries and concentrates on broader aspect of that process. It shows that transformation happening in Indian pharmaceutical firms has not been explored by both strands of researchers.

Chapter 4 presents the theoretical framework used in this research for exploring the firm level processes involved in discontinuous or dynamic learning for the development of new knowledge creation capability for innovation in Indian pharmaceutical firms. The theoretical framework is based on the absorptive capacity concept and builds on earlier frameworks which have focused on organisational knowledge creation. It draws on the

strategic management and organisational theory literature focused on knowledge, learning and innovation. It shows the role of knowledge in developing capabilities for innovation and organisational processes involved in creating knowledge. The approaches used by large pharmaceuticals firms to transform their technological capabilities as a response biotechnological change guides the theoretical framework.

Chapter 5 discusses the research methodology. This chapter explains rationale for conducting the research in two phases and choosing case study as a research methodology in second phase. It explains in detail how the interview questions were framed to make theoretical framework operational. This chapter concludes with a discussion on the method employed for the data analysis.

Chapter 6 describes the historical evolution and important characteristics of the Indian pharmaceutical industry. It presents the capability creation model and discusses the long term technology capability accumulation process in Indian pharmaceutical industry. It also illustrates the impact of institutional environment on learning process involved in technological capability accumulation process.

Chapter 7 introduces cases of the six innovative Indian pharmaceutical firms. It describes the evolution of organisational capabilities and discusses processes used by these firms' to transformed strategies, markets, product portfolio and capabilities as a response to change in patent law.

Chapter 8 focuses on the learning processes involved in development of capability for innovation in firms under study. It presents analysis of inter-firm similarities and differences in terms of learning processes and its influence on development of the innovative capability. This chapter concludes with pointing out the limitations of learning hierarchy models.

The dissertation concludes with Chapter 9. The chapter begins with a research summary and follows that with discussion about main contributions that can be drawn from our research. This discussion covers relevance of research to practising managers, academic literature and policy implementation. Finally the thesis provides an insight into limitation of research and direction for future research.

Chapter 2

RESEARCH CONTEXT

2.1 Introduction

This chapter provides a general overview of the research context. It focuses on the effect of change in patent law on firms from developing countries as a result of World trade organisation (WTO) agreements. This forms the genesis of the research presented in this thesis.

The WTO agreements are influential in reducing the tariff and non tariff barriers of international trade. These agreements were developed through a series of trade negotiation rounds, held under General Agreement on Trade and Tariffs (GATT). The GATT, a trade pact and organisation was founded in Geneva in 1948 to pursue the objective of free trade in order to provide equal growth and development to all member countries. The first seven rounds mainly focussed on tariff reductions but later negotiations included other areas such as anti-dumping and non-tariff measures. The culmination of the negotiations in the last round — the 1986-94 Uruguay Round — created the WTO on 1st January, 1995. WTO agreements are thus instrumental in setting uniform rules and regulation for trade in goods as well as services all over the world and therefore in recent years it has emerged as one of the main backbone of globalisation process. According to Govindrajan and Gupta, (2000) this reduction of tariff and non tariff barriers along with the advances in information and communication technologies is playing a key role in driving a globalisation process by facilitating trade among different countries.

However, the WTO agreements became a very controversial issue with the introduction of intellectual property laws as the third leg of the WTO in the form of 'Trade Related Intellectual Property Rights (TRIPS). Bhagwati (2002) an advisor to the WTO questions the validity of IPR as an instrument of trade and suggests that the WTO now rests on a tripod whose third leg, namely TRIPS, is shorter than the other two, goods and services. For many decades the intellectual property rights issues were highly contentious and now with the passing of TRIPs agreement, they have again became a highly debated and controversial issue. Machlup (1958) shows the long history of doubts about the patent system expressed by European and American economists. In the TRIPS agreement, the contentious requirement of strengthening the patent regime for pharmaceutical and agro-chemical products brought highly sensitive issue of healthcare and welfare into sharp focus

especially from the developing countries perspective. This led several developing countries questioning the motives of WTO agreements.

Two – third of the WTO members (around 146 countries) are developing and least developed countries and industries from these countries are certainly going to be affected by the emerging 'trade' regimes. According to Rodrik (1997) in the emerging new trade environment developing countries now have to implement an agenda of reforms that took today's advanced countries generations to accomplish. It is clearly evident that this change in the 'rules of the game', specifically the strengthening of IPR regimes will exert significant pressure upon sectors like pharmaceuticals, chemical and agro chemical that have long enjoyed protection and an assured domestic market (Das and Nair, 2000). Therefore the changes in patent regulations due to the TRIPS and its impact on learning processes in knowledge based industries like pharmaceuticals from developing countries forms the genesis of this research. It raises the question:

How are firms from a developing country building a strategic knowledge creation capability for innovation as a response to the forces of globalisation?

This chapter gives an overview of debate about various issues about intellectual property laws and its linkages with current research.

Section 2.2 discusses the various issues related to the patent system and shows the difference between the evolution of patent systems in advanced and developing countries. Section 2.3 then concentrates on the Trade Related Intellectual Property Rights agreements (TRIPS) and its consequences on patent regulation all over the world. Section 2.4 reviews the literature regarding the changes of patent systems and their impact on the domestic pharmaceutical industry in different countries. Section 2.5 presents the characteristics of the Indian pharmaceutical industry which is the focus of this research. Finally this chapter concludes with the research questions.

2.2 WTO and Patents – Trade Related Aspects of Intellectual Property Rights

Over the years advanced countries have strengthened their patent system whereas the developing countries showing different needs and priorities have set up weak patent laws or in some cases these countries have reduced the strength of patent system. But the growing role of the US in the late 1970s as a major producer of know-how and the catching – up process in newly industrialising countries led to a growth of pressure from the US on these countries to strengthen their patent laws. This pressure was triggered by significant inroads by newly industrialising countries into US markets and increasing trade

deficits (Granstrand, 1999). From the beginning of the 1990s, US industries through various initiatives started pushing for stronger patent laws domestically as well as internationally. This led to the incorporation of intellectual property rights (IPR) laws as a trade issue in the Uruguay round of negotiations of GATT and this finally resulted in the TRIPS agreements.

The intellectual property right is a grant intended to allow the holder to prevent others from making commercial use of innovation for a limited period of time. The intellectual property system comprises a number of legal instruments like patent, designs and trademarks along with copyrights. Under the modern patent system there are three main requirements which patent applications have to fulfil: novelty – some degree of difference to any previous innovation; non-obviousness – the innovation is not apparent to someone who is technologically competent in the field; and utility – there is a specified commercial purpose to innovation. There was wider agreement about the basic requirement of the patent system but the strength or efficacy varied a lot between countries.

The TRIPS agreement is now instrumental in universalising the standards of intellectual property rights all over the world and framing equal 'rules of the game' for advanced as well as developing countries of the world. It is the most important instrument to date concerning intellectual property protection. It covers the seven IPRs such as copyright and related rights, trademarks, geographical indications, industrial designs, patents, layout-designs of integrated circuits and undisclosed information. Among all these, 'patents' is the most important form of IPR for industrial firms operating in the advanced as well as developing countries

The next section summarises the history of the development of the patent system and illustrate the different interpretation in advanced and developing countries.

2.3 Brief History of the Patent System

The historical evolution of the patent system in the advanced countries is well documented by David (1993), Penrose (1973), Machlup (1958) and Granstrand (2003). The first patent law is attributed to the Republic of Venice and dates from 1474. The patent code incorporated various ideas and inventions shown to be workable and useful; and these ideas and inventions received ten years of protection subject to compulsory licensing.

The Patent laws spread in Germany and England in the 16^{th} and 17^{th} century and by the early 19^{th} century across the whole Europe while the US congress passed its first law of patents in 1793. In Europe, England reviewed its patent system several times in the period 1851 to 1872. According to McLeod (1991) presence of patent system played an influential role in shaping the industrial revolution. The patent system in the US evolved differently

from the Europe. Initially the patent institutions in the US were derived from those of Britain's North American colonies but from 1790 to 1836, as a net importer of technology, the US restricted the issue of patents to its own citizens and residents. Even in 1836, patents fees for foreigners were fixed at ten times the rate for US citizens and residents, and only from 1861 foreigners were treated on a non – discriminatory basis (CIPR Report, 2002).

The first important landmark in historic evolution of patent system is 'The Paris convention of 1883' – proposed and formalised by a select group of industrialised countries. It is the first multinational treaty on intellectual property rights which was signed and ratified by many countries. This convention specified that national patent system should treat domestic and foreign applicants equally and accept patent applications up to a year after the first application in another member country. Apart from these regulations, the member countries were free to determine the standards, subject matter and period of protection. This convention left countries entirely free to establish the criteria for patentability and the strength of protection offered to patent holders (Penrose, 1951). The basic tenets of the patent law in advanced countries are thus based on the Paris convention of 1883.

In recent years the patent system in advance countries has broadened the scope of domains of patents by accommodating the emerging technologies from advances in fundamental sciences like patenting of live organisms and in some cases it gave rise to the whole new industry like biotechnology. However, as David, (1993) points out by widening areas of dispute, the patent system also raised new questions and created many 'awkward ambiguities' especially in case of new technological industries like biotechnology and information technology. A major source of difficulties is the problem of achieving consistency in the application of legal principles, preserving the force of precedent and likely costs of entailed litigation and innovation. It has been noted now that with the changing nature of technology, the application of patent and copyrights is rather ill suited to some of the new technologies (WIPO, 1989)

The historical evolution of patent laws in the developing countries has differed a lot from the advanced countries. Most of the developing countries were colonies till World War II and after independence they continued with the same regulations of colonised era. The regulations slowly started changing in the 1960s and 1970s as most of the developing countries either abolished or weakened their patent laws; for example, Turkey weakened its patent law in 1961, Brazil in 1969 and India in 1971. The main reason behind this was the argument that a patent system would not be stimulus to innovative activities in developing countries because these countries have little capability to innovate. The market

in the developing countries has a huge need but very little purchasing power providing low incentive for innovation. Also the developing countries had very few inventions worth patenting in advanced countries and so they can not expect the reciprocal advantages from granting patents to foreigners (Penrose, 1973). This belief that developing countries will suffer the negative consequence of patent monopolies granted to foreign investors created the weak patent regimes in these countries.

However, with emergence of the US industry as an innovative technology producer, the US government started pressing for a 'trade based approach' to improve IP protection while trading with weak IPR regime countries. It enacted the Trade and Tariff Act (1984 amendments) which in section 301 specified that countries could be removed from the privileged trade status if they did not provide effective minimum safe guards for the acquisition and enforcement of the intellectual property rights. Brazil and India were penalised through this provision and South Korea was pressured into reforming its patent law; Mexico and Chile did the same with effect from 1992, Brazil changed it in 1997 (Kaplinsky, 1989).

Different arguments were put forward in regarding the strength of the patent system mostly focussing around its role in economic growth, technology transfer and foreign direct investment. The next section briefly discusses them.

2.3.1 Strength of Patent system and its economic implications

Over the years studies covering the strength of patent system and its role in development of technological and innovative capabilities have largely shown sharply conflicting views.

2.3.1a IPR and economic growth, innovative activity

The broad argument put forward in support of a strong patent system relates to the issue of development and economic growth. Researchers claim that intellectual property rights have a significant role as an incentive for spurring innovation (Kanwar and Evenson, 2003). Arrow (1962) argues that there is a tendency in industry to under invest in R&D and patent protection is one of the several alternatives of appropriation that act as an encouragement for industry to invest in R&D.

Mazzoleni and Nelson (1998) summarises four different broad theories that has been put forward to explain the purpose of patents: patent protection motivates inventions, induces development and commercial inventions, promotes disclosure of inventions and it enables orderly development of broad prospects.

It is argued that the strong patent system stimulates innovation by granting the innovator a limited period of exclusive control of the right to use, manufacture and sell the innovation.

The principle way a patent affects invention and innovation is through its effects on the rate of imitation. Thus a delay in imitation through patent protection and the resultant period of exclusive rights would be a stimulus for firms to invest in R&D. Based on the distinction between invention on one hand and development and commercialisation on other had it is argued that patents plays an important role in inducing firms to commits resources to the development of inventions as holding of a patent at an early stage provides assurance that, if development is technologically successful, its economic rewards can be appropriated. However Mazzoleni and Nelson (1998) points out that the effectiveness of patent protection varies from industry to industry and in most industries patents were not an important part of the incentives firms have for investing in the R&D. Also in many industries patents are not needed to induce further development from invention; a head start on commercialisation can yield large profits (Mansfield, 1986; Levin et al, 1987; Cohen et al, 1997). It also argued that a patent system as an incentive to innovation will be at the expense of society as the exclusive rights conferred by the patent system enables the innovator to charge monopolistic prices during the lifetime of the patent (Arrow, 1962; Nordhaus, 1962; Scherer, 1972).

The other major justification for the patent system is that the patents are incentive for innovators to make disclosure of their innovations which they might otherwise keep secret. It therefore creates a way of quick and wide diffusion of technical information underlying new dimensions. However, critics have raised concerns regarding the quality and quantity of the disclosures and utility of the information provided in patent disclosures (Sideri, 1994).

Recently another argument for the patent system has emerged that it provides a legal base to facilitate the process of technology licensing and research collaboration. This has been argued to be particularly important in cases of collaborative research (Scothmer, 1991), when the innovator lacks the 'complimentary assets' to successfully commercialise an innovation (Teece, 1986). However, Merges and Nelson (1990) show through various cases from different industries that across the board strengthening of intellectual property rights courts the danger of increasing litigation conflicts and cost of innovation.

Other complex issue related to patent system as an incentive for innovation include optimal breadth or scope of a patent as well as optimal combination of length and breadth (Gilbert and Shapiro, 1990; Klemperer, 1990). In the context of the strengthening of patent laws around the world, Mazzoleni and Nelson (1998, pp 273) conclude that "there is a reason for concern that the present movement towards stronger patent protection may hinder rather than stimulate technological and economic progress".

2.3.2 IPR and developing countries

In the context of developing countries arguments about the influence of patent systems especially in the context of technological capabilities are focused on foreign direct investment, technology transfer and trade.

It is argued that the stronger patent systems promote technological development by encouraging the acquisition of technology by market mediated mechanisms like technology licensing and foreign direct investment (Ferrantino, 1993; Mascus and Penubarti, 1995; Smith, 2001). The fear of imitation and reverse engineering will prevent the transfer of technology in the case of a weak patent system. Mansfield and Lee (1996) in a sample of 14 countries find the perceived weakness of intellectual property protection adversely affecting the volume as well as the composition of US FDI inflows to other countries. Empirical evidence shows that, other things equal, countries with stronger IPRs do attract more imports, though the effect varies across industries, however this 'favourable' impact of strong IPRs has generally been confirmed by a number of studies (for example Ferrantino, 1993; Mascus and Penubarti, 1995; Smith, 2001). These studies also argues that the result shows that foreign firms prefer exporting less to countries with weak intellectual property rights in order to avoid their products being copied by local firms. However researchers point out that the same findings also implies that stronger protection may encourage arm's length licensing of knowledge and reduce the need for undertaking direct investment (Mascus, 1998; Yang and Mascus, 2001).

The other important argument put forward in support of strong patent systems is that it promotes technology transfer through MNCs establishing R&D subsidiaries (Ferrantino, 1993; Mansfield, 1994). However Kumar (1996) suggests that availability of abundant trained low cost human resources and scale of ongoing R&D in the specialised knowledge fields of MNCs appear to be more important considerations for location of R&D than the strength of the IPR regime.

The arguments supporting the weak patents regime argues that the weak protection of IPR helps the cheap acquisition of technology through imitation or reverse engineering. Several studies of East Asian countries have pointed out the importance of non market mediated mechanisms like imitation in facilitating the firm level technological learning (Kim, 1997b; Hobday, 1995; Nelson and Pack, 1999; Lall, 2000; Amsden, 1989). It has been argued that the learning that is required in imitation or reverse engineering may be absent in market mediated acquisitions. Weak patent systems increase the opportunities for firms in developing countries to adapt and improve knowledge acquired from foreign sources. The basic and intermediate innovative capabilities learnt as a result of the imitative learning can give firms a head start for accumulating the advanced innovative capabilities.

The TRIPS debate basically centred around the arguments relating to technological development, FDI and technology transfer and reduction to barrier of trade by having uniform patent systems. The other argument was related to the perception that firms from advanced country firms were losing sales due to the weak patent systems in developing countries. It was this loss of potential profit which originally motivated advanced countries especially the US to bargain hard to bring intellectual property rights within the purview of the GATT/WTO.

Now with the signing of the TRIPS agreement, patent systems all over the world will converge with the IPR regulatory systems practised in advance countries. This will have enormous implications for the healthcare sector in developing countries as out of the seven IPRs cover by TRIPS; three aspects have a direct impact on pharmaceuticals – patents, trademarks and the protection of undisclosed information or trade secrets. These are discussed in the next section.

2.3.3 TRIPS agreement and its implications

The TRIPS agreement is a big and difficult step for firms operating in the knowledge intensive sectors from developing countries. It specifies the stronger levels of IPR protection, endorsing the perspective that countries should provide strong patent systems to benefit from technological licensing, FDI and investment in research and development.

The TRIPS agreement contains seven parts, Part I contains the general provisions and basic principles which govern the agreement; Part II, the substantive, minimum standards on seven intellectually property rights (IPRs); Part III, procedures and measures for their enforcement; Part IV, arrangements for the prevention and settlement of disputes; Part V, maintenance of IPRs and related procedure; Part VI, transitional arrangements and Part VII, the other final provisions for the implementation of the agreement.

In the case of pharmaceuticals and agro chemicals, patents will now be granted both for products and processes for inventions in all fields of technology, subject to the classical criteria of patentability i.e. novelty, non obviousness (or inventive step) and usefulness (or capability in industrial application). There can be no discrimination between imported or locally produced products (Article 31). The patent term will be twenty years from the date of application, applicable to all members of the WTO (Article 33).

Compulsory licensing is a very important issue for the developing countries. According TRIPS agreement the use of patents without the authorisation of the rights holder should be decided on a case by case basis and no across the board licenses will be permitted (Article30). Importantly in the case of a dispute on infringement, the responsibility of

proving innocence lies with the accused rather than in proving the infringement of the accused by the patent holder (Article 34).

This broad regulatory framework will now guide and control the pharmaceutical industry in WTO member countries. The TRIPS agreement became effective on 1st January, 1995. Advanced countries were given 1 year to comply whilst developing countries and transition economies were given until 1st January, 2005. For developing countries that required national patent law amendments to introduce patents for pharmaceuticals, such action could be delayed up to January 2005. Least developed countries are expected to enact TRIPS in 2016 with respect to pharmaceutical products. However Article 70:8 made it mandatory for members to accept patent applications for pharmaceutical and agricultural chemical products from 1st January, 1995 itself. Such products were to be granted exclusive marketing rights (EMRs) for a period of five years from the date of marketing approval in these countries or until the patent is granted or rejected, whichever period is less, provided that a patent application has been filed and patent granted after 1st January, 1995 and marketing approval obtained there. This means that at the minimum all pharmaceutical inventions for which patent applications were sought in any WTO member nation from 1994 onward have been covered by TRIPS obligations. In sum, all developing countries that did not previously do so, now had to make available patent protection for pharmaceutical inventions from 1995 onwards. The economic effects of which could be expected to begin at the earliest from 2000 onwards (when new drugs begin to get exclusivity under TRIPS provisions) and plateau by 2015 (when newly patented products may off set by older products losing their patent protection) (Scherer and Watal, 2001).

For developing countries these changes in patent regulations are more important due to well documented relationship between patent and pharmaceutical products and its subsequent influence on a country's health care policy.

The next section discusses the importance of patents in pharmaceutical industry and reflects on the implications of TRIPS for pharmaceutical industry in developing countries.

2.4 Patents and the pharmaceutical industry

The pharmaceutical industry is among the most R&D intensive industries, measured by the percentage of sales devoted to such activities (PhRMA, 2004). This industry is significantly different from other high tech industries in that the R&D process is made of different phases which are stringently controlled by regulation and therefore it takes 10-15years from initial discovery to the commercialisation of the drug. At each stage a firm needs to invest a lot which makes pharmaceutical R&D a very costly and risky process. Effective IPR protection is seen by the pharmaceutical industry as critical for it to recoup

its large R&D expenditures. In pharmaceutical industries patent have the ability to provide strong appropriation and profit maximisation by conferring limited monopoly rights to inventors. Chemical products are easy to patent because of structure of the molecule of each product is different; therefore it is difficult to invent around drug product patents. So the strength of the patent regime plays an important role in pharmaceutical firm's strategic decision making.

Many studies have shown the prominent role of patents in the pharmaceutical industry and the important link between strength of patent protection and investment in R&D (e.g. Mansfield, 1986; Levin et al., 1987; Taylor and Silberson, 1973). Mansfield (1986) showed that around 65% percent of pharmaceutical and 30% percent of chemical inventions would not have taken place but for patent protection while in most other industries patent protection doesn't play such a critical role. Levin et al., (1987) confirmed the importance of patents in pharmaceutical by showing that product patents were found to be highly effective as a means of appropriating returns only in 5 of 130 narrowly defined industries. These five included drugs, organic chemicals, and pesticides among others.

The availability of medicines is an important component in any country's healthcare policy and hence the strength of an IPR regime is a sensitive issue for different countries. In the case of diseases like AIDs the availability of drugs at affordable prices makes the difference between life and death. Due to this reason even different developed countries tightened up their patent laws after assessing the capability of their domestic pharmaceutical industry. Full patent protection for pharmaceuticals was not introduced until: 1949 in UK, 1960 in France, 1968 in Germany, 1977 in Switzerland and 1978 in Sweden (Nogues, 1993). Due to the pressure from the European Commission, Italy also introduced pharmaceutical patent protection in 1978. Spain and Portugal revised their patent laws in 1992 as a requirement for joining the European Union.

The world pharmaceutical industry is geographically highly concentrated with firms from a few developed countries accounting for the bulk of world production. Almost 82% of the world production in 1990 was in advanced countries with developing countries accounting for only 18%. This imbalance regarding the concentration of industry influenced developing countries to reduce the strength of their patent systems.

2.4.1 Patents and pharmaceutical industry in developing countries

In the past many developing countries were dependent on imports for vitally needed drug supplies, which made the costs of imported drugs and policies to reduce them, a matter of national concern. In some developing countries the market share held by foreign firms has been higher than 50% and has even reached 80 to 90% in some cases (Watal and Mathai.

1995). Therefore the weakening of the patent law in developing countries often targeted pharmaceutical, chemical and food technologies where protection was either excluded or only minimal protection was given. Food and medicine were seen as essential needs of the population and the weakening of patent laws was seen as a protection from means by which firms can create monopolistic control.

The learning process involved in development of pharmaceutical manufacturing and R&D capabilities is much more complex compared to other sectors. The large multinational firms that dominate this sector develop a significant proportion of knowledge and through patent effectively control the diffusion of knowledge. These firms conduct most of their activities at home or in other developed countries and prefer direct investment to licensing when producing abroad. Therefore most of the developing countries have built domestic pharmaceutical industries by adopting weak patent laws which provided protection only to the production processes, not products. This allowed the manufacturing of the same product albeit with small modifications in production processes. This started the trend of reverse engineering in developing countries. On the basis of reverse engineering these countries developed the domestic pharmaceutical industries and some countries now are not only just serving basic domestic needs but also exporting some of their products (see Table 2.1). Countries like Argentina, Mexico, Brazil, Egypt, Turkey, Colombia, and Indonesia are capable of servicing domestic demands while countries like India, South Korea and China even figure amongst the 20 largest pharmaceutical exporters. These countries have developed enough capability to produce active pharmaceutical ingredients and are now exporting drugs to other developing countries as well as to the highly regulated generic markets in advanced countries.

However, this entry of pharmaceutical firms from developing countries in global generic markets along with changes in large pharmaceutical firms' business model led to increase in pressure on developing countries to strengthen their patent laws. In the last two decades large pharmaceutical firms based in advanced countries have came under heavy regulatory, social and economical pressure. The increasing cost of drug discovery due to stringent drug regulations, public pressure to reduce healthcare bills and competition from generic industries has led to an erosion of profits. In this context, the growing size of developing country markets for patented drugs became evident, along with possible opportunities to reduce drug discovery cost by outsourcing non critical parts like clinical trials in developing countries created new benefits for large pharmaceutical firms to push the developing countries for the strengthening of patent laws. Due to these emerging opportunities, harmonisation of the patent protection system in industrial economies and making developing countries introduce product patent protection became important part of

large pharmaceutical firms' strategies in particular US pharmaceutical industry. The US pharmaceutical industry played a decisive role in bringing intellectual property into GATT agenda in 1986, and in the development of relevant rules, as contained in the TRIPS agreement (Ryan, 1998, pp68-69).

Table2.1: Examples of pharmaceutical industries in developing countries at different stages of technological development (Source: adapted from Ballance et al., 1992)

Stage 1. No production capabilities		
Bahrain	**Laos**	**Senegal**
Botswana	**Maldives**	**Swaziland**
Iceland	**Oman**	
Stage 2	**Production capabilities for formulations**	
Algeria	**Ecuador**	**Kenya**
Bangladesh	**Hong Kong**	**Madagascar**
Chile	**Iran**	
Stage 3. Production capabilities for both active ingredients and formulations		
Argentina	**Cuba**	**Korea**
Australia	**Egypt**	**Norway**
Bolivia	**Hungary**	**Poland**
Brazil	**India**	**Spain**
Bulgaria	**Indonesia**	**Turkey**
Canada	**Ireland**	**Russia**
China	**Mexico**	

The degree of patent protection given to pharmaceutical products in the past was clearly related to the development of domestic pharmaceutical industries. Now due to the TRIPS agreements for the first time in international law, all countries are required to provide protection to both process and product inventions. This strengthening of patent law will certainly restrict reverse engineering or imitative R&D. In some developing countries like India, Argentina and China the absence of product protection played a crucial role in the development of the domestic pharmaceutical industry and would be severely affected by TRIPS (Watal and Mathai, 1995).

The next section will review some of the literature on studies covering strengthening of patent law and its effect on pharmaceutical industries in developing countries.

2.4.2 Implications of strengthening the patent law and its effects on pharmaceutical industry:

Pharmaceutical industries in developing countries have been the subject of a number of empirical studies about the influence of the strengthening of patent regime focusing on socio economic issues like pricing of the drugs and welfare cost (see for instance, Lanjouw, 1996; Watal, 2000; Scherer and Watal, 2001; Pangariya, 1999; Nogues, 1993). These studies although inconclusive point towards increase of prices in case of the patented medicines and significant welfare losses. Some of the researchers have

a. investigated the link between strengthening of patent system and its effect on the technological development (Sequeria, 1998; Kumar, 2003; D'Este, 2002) and

b. analysed the effects of strong patent system in output and trade performance of the industry (Weisburst and Scherer, 1995; Felker et al., 1997).

But not enough attention is paid to the impact of changed patent law on the learning process involved in building technological capabilities in pharmaceutical firms from developing countries and resultant responses from firms to transform their competencies.

Most of the research examining the effects of changes in patent law on pharmaceutical industries has been focused on investigating the link between strengthening the patent system and the effect on the technological development of pharmaceutical industries (Sequeria, 1998; Kanwar and Evenson, 2003). For instance Sequeria (1998) investigated the effect of strengthening the patent regime on technological development in the Spanish pharmaceutical industry. He found that in general a strong patent system did not influence the development of production capabilities but had a marginal influence on the rate of accumulation of innovative capabilities through reorienting the 'culture' of the industry towards attaching greater importance to innovation. According to Kumar (2003) the strengthening and harmonisation of the IPR regime affect the process of technological development of poorer countries in a significant manner by choking an important contributor of growth that has been variously described as imitative duplication or reverse engineering. Some studies like D'Este (2002) notes that a change in the regulatory rules significantly alters the business environment and imposes the adaptation of new behaviours. In the Spanish pharmaceutical industry strategies of the firms differed markedly between those conducting innovative activities and those specialising in the marketing of branded generics.

Some studies have analysed the effects of patent system in output and trade performance of the industry. In the case of Italy (Weisburst and Scherer, 1995) and Hungary (Felker at al., 1997) the bulk pharmaceutical production growth rate declined after the introduction of a

strong patent system. In the Italian case the modest trade surplus in pharmaceuticals of $40.6 million in 1979 was converted into a trade deficit of $827 million by 1988 (Challu, 1995) and within a decade of strengthening the patent regime Italy lost domination over drugs export market to other countries. The studies have consistently shown that strong patent systems are associated with increasing foreign firm's market shares. In the case of Japan and Italy the introduction of strong patent systems has led to an increase in the market share of foreign firms. In Italy Weisbrot and Scherer (1995) shows large scale foreign acquisitions of small and medium sized domestic firms.

Felker et al., (1997:33) states that in the case of Hungarian pharmaceutical industry, prior to 1970 most research was aimed at developing processes for copying products, but since the 1980s firms have sought to rely on their own R&D for product development to complement foreign licensing. Similarly Madanmohan and Krishnan, (2003) suggest that in the case of Indian pharmaceutical firms response to changes in patent law, the predominant strategy Indian firms is to build capacity to achieve scale economics while the other preferred strategy is to stabilise and control the environment through developing alternative technology trajectories.

In the case of Indian pharmaceutical firms the important constituent of alternative technological trajectories is innovative process and product R&D. Therefore this research focuses on learning processes adopted by Indian pharmaceutical firms to transform from imitative R&D to innovative R&D as a response to change in patent law. It explores the question of developing knowledge creation capability for innovation by studying the case of Indian pharmaceutical industry.

The next section will provide the rationale for choosing Indian pharmaceutical industry as a case study and presents the important characteristics of the industry.

2.5 The Indian pharmaceutical industry

The Indian pharmaceutical industry is the 13th largest in the world in terms of market output; accounting for a market of about US$ 2.5 billion (Ramani, 2002). Today it is ranked as the most advanced pharmaceutical industry amongst developing countries and one of India's best in science based industries. The Indian pharmaceutical industry has developed wide ranging capabilities in the complex field of drug process development and production technology. It is well ahead of other developing countries in terms of process R&D capabilities and the range of technologically complex medicines manufactured. The Indian pharmaceutical industry comprises 250 large units which include public sector, Indian companies and foreign subsidiaries and 8000 small scale units. These 250 large

units have an almost 70% share of pharmaceutical activity and therefore dominate the Indian pharmaceutical sector.

The growth of the Indian pharmaceutical industry was very slow till 1970. The patent act of 1970 and government investment in the drug industry infused life into the domestic pharmaceutical industry. The increasing opportunities due to weakening of the patent law led to the entry of a number of manufacturers who set up production units of different sizes. The availability of trained manpower, comparative ease of imitation and a strong chemistry base among Indian research institutes supported the manufacturers and gave the Indian pharmaceutical industry its current profile.

This indigenous capability development in the Indian pharmaceutical industry represents one of the most successful cases of self reliant development in knowledge based industries from developing countries. The pharmaceutical industry is now a net foreign exchange earner and chief exporter of cheap generic drugs to the CIS countries, Latin America, USA, UK and Africa. The ability to produce cheap generic drugs makes the Indian pharmaceutical industry one of the most strategic industries not only for India but for other developing countries also.

The following section will describe the changes in the Indian regulatory regime concentrating on Patent Acts and its influences on technological development of Indian pharmaceutical firms.

2.5.1 The 1911 patent law

India inherited the Patents and Designs Act, 1911 from its colonial rulers. This patent act provided protection for all inventions except those relating to atomic energy. The duration of the patent term was 16 years from the date of application. During this era, the Indian healthcare sector was dominated by multinational pharmaceutical firms. A few Indian domestic pharmaceutical and chemical firms tried to develop their own technology but they ran into trouble with foreign patent owners (Kumar, 2003). Desai (1980) presents cases where foreign patent owners were neither using their patents for domestic manufacturing nor allowing those patents to be used by local firms and this observation is also reflected in the report of the second Patent Enquiry Committee (1957-59). This report points out that foreign patentees were acquiring patents not in the interests of economy of the patent granting country but with the objective of protecting an export market from competitors especially from developing countries. Due to such behaviour, drug prices remained out of the reach of the large Indian population creating a health care crisis. Lanjouw (1996) notes that during the era of strong patent laws drug prices in India were ranked amongst the highest in the world. The committee therefore recommended that, it

will be beneficial for India to adopt a patent system that is focused on ensuring access to resources at lower prices to its vast population. Desai (1980) suggests that Indian firms were not against patents in principle but wanted greater access to patented know-how especially when patent owners were not allowing their patents to be used.

However this dual pressure, from the needs of a vast population and from domestic firms, started building up in late 1960s and finally led to the weakening of the patent laws in the beginning of the 1970s.

2.5.2 The 1970 Patent Act

The Patents Act 1970 laid the foundations of the modern Indian pharmaceutical industry. It has been hailed as an ideal legislation for developing countries and became the model for other developing countries like Argentina, Mexico, Egypt, Brazil and Chile (Chandiramani, 2002).

The 1970 Patent Act removed the product patents for pharmaceuticals, food and agro-chemicals, allowing patents only for production processes. Since virtually any chemical compound can be made by a variety of processes, the scope of patent protection was greatly reduced. In the case of pharmaceutical, food and chemical patents, the statutory term was shortened to five years from grant or seven years from application, which ever was shorter and for other products the patent period was allowed up to 14 years. Compulsory licenses could be issued after three years. The 1970 Patent Act greatly weakened intellectual property protection in India, particularly for pharmaceutical innovations. It started the era of reverse engineering where firms developed new products by changing their production processes. The entrepreneurial pharmaceutical distributors and scientists used the opportunities provided by patent law to establish a profitable pharmaceutical business. The absence of a product patent regime gave Indian pharmaceutical firms a breathing space and allowed them to learn the basics of pharmaceutical R&D. A number of quantitative studies have shown that the abolition of product patents in chemicals and pharmaceuticals has facilitated the development of local technological capability in the Indian pharmaceutical firms (e.g. Fikkert, 1993; Haskar, 1995; Kumar and Saquib, 1996). Fikkert (1993) found that the weak patent regime played a crucial role in the development of R&D in Indian pharmaceutical enterprises and specially in absorbing considerable foreign technology. Two decades after 1970 the Indian pharmaceutical industry emerged as the highest R&D spender and among the most innovative sectors of the Indian industry (Kumar and Saquib, 1996). However, the weakening of patent laws had some negative impact in terms of R&D technology transfer and Raizada (2002) acknowledges that citing the drop in patent registrations in India. The

number of patents granted per year fell by three quarters over the following decade, from 3923 in 1970-71 (of which 639 were to Indian applicants, 3294 to foreign applicants) down to 1,019 in 1980-81 (349 Indian, 670 foreign)

Indian pharmaceutical firms have shown incredible skills in reverse engineering R&D and now account for 70% of bulk drugs and 80% of formulations produced in the country (Hamied, 1993). By 2000 out of the top ten firms, in terms of market share, six were Indian firms unlike the 1970s when the list was dominated by the subsidiaries of foreign multinationals (OPPI, 2001).

From the early 1990s Indian companies were making the international quality products with increasing sophistication. This is reflected in the increasing share of Indian firm's revenue coming from exports, a sign of increasing maturity as well as a rise up the value chain by Indian pharmaceutical manufacturers. However this process of gradual capability building was truncated by the signing of WTO agreements and the introduction of full fledged patent protection to pharmaceutical products.

2.5.3 The Indian patent law 1999 – Compliance with TRIPS

The signing of WTO agreements has put the Indian pharmaceutical industry at the threshold of a major transformation. The 1999 Patents Act strengthens the patent protection along the lines specified by the TRIPS agreement (Table 2.2). Therefore it introduces the recognition of product patents for pharmaceuticals, food products, agro chemicals and micro organisms. Among other changes, increased in the life of patent from existing seven years to 20 years have important implications for drug related healthcare issue.

Products that were patented before 1995 and already in the Indian market remain free of patent protection. This means that a large amount of existing medicines which are basic in nature remain available off-patent. However Indian pharmaceutical firms will not be allowed to reverse engineer new technologies or molecules without formal licenses from patent holders. This means that a main source of molecules for Indian industry will be blocked. Most of MNC pharmaceutical firms who hold the patents for new technologies or molecules have already established a presence in the Indian market and those who have not are preparing plans to enter Indian market. Therefore as Halemane and Dongen (2003) indicate, Indian companies will have to look for new sources of growth in future. Large Indian pharmaceutical firms have recognised the change in rule of the game and the importance of innovative R&D for long term survival and success.

Table2.2: Indian patent act of 1970 and TRIPS

	The Indian Patent Act , 1970	**The Indian Patent Act, 1999**
1.	No product patents allowed for pharmaceutical, food products and agrochemicals. Only process patents. No patents for micro organisms.	Both product and process patents for pharmaceuticals, food products and agro chemicals, and micro organisms.
2.	Process patents for the above have a statutory term limit of the shorter of 7 years from application or 5 years from granting.	All patents have a term for at least 20 years from filling.
3.	Government retains wide powers to grant compulsory licenses.	No automatic licenses, compulsory licenses only in cases of national emergency.
4.	Importation does not fulfil working requirement	No discrimination between domestic production and importation
5.	In all cases, the burden of proof in an infringement case falls on the patentee.	In the case of infringement, the burden of proof lies with alleged infringer (reversal of burden of proof).

The challenge facing the industry is to make a transition from the era of protectionism to an era of global competition. Indian pharmaceutical firms are applying different adaptive strategies like vertical integration, capacity additions, brand acquisition strategy, marketing channels integration strategy and R&D integration strategies as a response to change in patent law (Madanmohan and Krishnan, 2003). Among them the most ambitious and challenging strategy is to develop new competencies for innovative R&D. In the pharmaceutical industry innovative R&D represents new chemical entities or new drug delivery systems. But it also represents an enormous challenge for firms due to the infrastructural and financial resources involved in innovative R&D and more importantly the difference of knowledge bases involved in innovative and imitative R&D.

2.5.4 Challenge of knowledge base:

The Patent act 1970 enabled the Indian pharmaceutical industry to develop skills in reverse engineering and to produce the alternate processes for drugs. Reverse engineering or imitation was the mechanism of knowledge acquisition used by firms in Indian

pharmaceutical industry to acquire outside knowledge and develop skills in process R&D. This process of reverse engineering involves copying of existing molecules by manufacturing them with a different process. As a result the Indian pharmaceutical firms had their knowledge base firmly rooted in organic and synthetic chemistry. Indian pharmaceutical firms had not made any efforts to acquire other scientific disciplines to create or develop innovations or novel products (Ramani, 2002). However innovative product creation in pharmaceutical R&D is a very complex process and requires integration of different specialised knowledge bases like organic, medicinal chemistry along with biology and pharmacology. This difference of knowledge base in imitative R&D and innovative R&D is reflected in Bell and Pavitt's (1995) observation that 'across a range of industries and technologies, increasing specialisation has widened the gap between the kinds of knowledge and skills required to use given technologies and those required to create and change technology'.

Therefore the distinction between the ability to produce a product by imitation or ability to copy technology or use the given technology and capability to generate it or create and change technology, have profound implications in pharmaceutical R&D. The difference in scientific knowledge base along with managerial and organisational issues of managing knowledge creation process adds up the complexities. So it raises the questions:

- **How are Indian pharmaceutical firms building knowledge creation capability for innovation as a response to change in regulations?**
- **How relevant is knowledge accumulated through imitation for firms in their efforts to create innovative novel products?**

In the new environment, Indian firms have to under go dynamic learning to develop new competencies. The process of technological learning and of progressing from imitation and reverse engineering to establishing a genuine indigenous innovative capability must now be done differently from the past.

2.6 Summary

This chapter presented the genesis of research along with detailed overview of the issues related to that. It discussed different issues related with patents, evolution of the TRIPS agreement and its impact on pharmaceutical industry especially in the developing countries. The change in regulation as a result of the TRIPS agreement raised some questions for pharmaceutical firms in developing countries. This chapter concluded with a presentation of those questions, specially focusing on the ability of the firm to transform its

capabilities and develop new competencies as a response to the turbulent external environment.

The next chapter reviews the literature focused on capability accumulation, creation and transformation based on firms from advanced as well as developing countries.

Chapter 3

LITERATURE REVIEW

3.1 Introduction

This chapter reviews the developing country and strategic management literature within the field of technological capability development and concentrates on broader aspect of that process.

The focus of this research is development of knowledge creation capability for innovation in firms from developing countries as a response to change in the external environment. It analyses processes involved in discontinuous learning for development of new capabilities which have received little attention in context of firms from developing countries.

The literature on firms from developing countries mostly focuses on the issue of long term process of technological capabilities accumulation in industries and firms from these countries. Researchers studying technological capability development in developing countries suggest that in the earlier stages of technological development, firms in developing countries mostly acquire technologies which are matured in advanced countries. This acquisition is mostly done through formal channels of technology transfer like licensing or joint venture or non formal channels like reverse engineering or imitation. The acquired technologies are assimilated and improved through indigenous technical effort regardless of the source and channel of technology transfer which finally results in technological development of firm and country (Bhagawati, 1996). However, changes in the world trade environment are limiting formal and non formal modes of technology transfer for firms in developing countries. The widening gap between kinds of knowledge and skill required to imitate or operate given technology and the kinds of knowledge required to create, generate or change technology has reduced the possibilities of acquiring the latter largely by experience in the former (Bell and Pavitt, 1993). Therefore in this new era the ability of firms in developing countries to create new knowledge for innovation has become a strategically important capability. So the explicit investments in acquiring and accumulating knowledge and skill have become the necessary basis for building firm's 'change generating' or dynamic capabilities.

The area of rebuilding or reconfiguring of capabilities has been addressed by strategic management literature (SML) however by focusing on innovative firms competing at technological frontiers in advanced countries. However such firm level studies of capability transformation to develop new competencies are absent in developing countries

literature. Also despite the emergence of more comprehensive firm level studies during mid -1990s (eg. Kim, 1997b; Dutŕenit,2000; Figueirdo,2003) inter firm comparative analysis of learning and capability accumulation in firms from developing countries or newly industrialising countries has still been a neglected area in this research stream. Indian pharmaceutical firms' transformation of capabilities to develop competencies in innovative R&D provides that opportunity.

Section 3.2 reviews the developing countries literature (DCL) regarding building technological capabilities and indicates the limitation of it in terms of research on firm level processes involved in learning and in rebuilding or renewing of the firm capabilities. Section 3.3 reviews the strategic management literature concerned with maintaining and renewing core capabilities or competencies in the most innovative firms. It also indicates the limited attention given to processes of long term capability accumulation in this research tradition. Section 3.4 then locates the topic of this research within the broader research areas covered by developing countries firm's literature and strategic management literature.

3.2 Technological capability accumulation in developing countries literature

This section reviews the developing countries literature about technological capabilities. It describes the emergence of technology capability as a concept, taxonomy and its application.

Bell and Pavitt (1993) distinguished capabilities in terms of production capabilities and technological capabilities and this research focuses on technological capabilities. The review shows that developing countries literature has not paid enough attention to organisational and managerial issues associated with management of technological knowledge, learning and innovation, albeit with some exceptions like Kim (1997a), Dutŕenit (2000) and Figueiredo (2003). It also reveals that there has been a complete lack of research on technological capabilities on firms in science based industry like pharmaceutical from developing countries.

3.2.1 Technological capability development: concepts

The processes involved in technological capabilities accumulation in firms and industries from developing countries have been the focus of attention for many researchers in the last 20 years. Over the years developing countries have rapidly accumulated and diversified their industrial production and technological capabilities. According to Dosi et al.. (2000) to be capable of something is to have a generally reliable capacity to bring that thing as a

result of intended action. Capabilities fill the gap between intention and outcome, and they fill in such a way that the outcome bears a definite resemblance to what was intended.

The technological capabilities are defined as "the stock of resources needed to generate and manage technical change, including skills, knowledge and experience and institutional structures and linkages" (Bell and Pavitt, 1993). The concept of technological capability is interchangeable with other concepts that refers to same idea, such as technological effort (Dahlman and Westphal, 1982; Lall, 1987) or technological capacity (Bell, 1984a; Katz, 1987; Scott- Kemmis and Bell, 1985); basically describing technological capabilities as "the ability to make effective use of technological knowledge". Production capabilities are defined as the "stock of resources used to produce industrial goods at given levels of efficiency and given input combinations: equipment (capital enabled technology), labour skills (operating and managerial know-how and experience), product and input specification and the organisational methods and systems used" (Bell and Pavitt, 1993). According to Bell and Pavitt (1993) technological accumulation refers to any process by which capabilities for generating and managing technical change are increased or strengthened, whereas they associate technological change with any process leading to a change in the existing set of production capabilities.

Technological capabilities refer to both; technical knowledge component which enables firms to generate innovations and organisation component which enables firms to manage the implementation of their in-house innovations and their linkages with external sources of knowledge. Production capabilities involve replicating the tasks while technological capabilities involve resources aimed at generating and managing changes in context of maintaining competitiveness in a changing environment (Bell and Pavitt, 1993). The distinction between technological and production capabilities reflects the increasing specialisation and professionalization of the activities involved in generating and managing change.

The processes by which technological capabilities are accumulated have often been referred to as learning (Bell and Pavitt, 1993). Firms build technological capabilities through learning processes, so technological learning refers to the dynamic process of acquiring, assimilating and applying technological knowledge. Technological accumulation refers to the process involved in learning over time, development of skills, knowledge and institutions that make country's capacity to generate and manage change. However building technological capability is not an automatic process; some latecomer firms succeed and others fail in catching up with the technological frontier (Dosi, 1988; Katz, 1987; Lall, 1992; Hobday, 1995; Bell and Pavitt, 1995).

3.2.2 Taxonomy of capabilities:

Lall (1992) based on the mastery and complexity of technological activities and drawing on Dahlman and Westphal (1982), Katz (1984), Dahlman, et al., (1987) and Lall (1987), presents taxonomy of firm level technological capabilities. Bell and Pavitt (1995) and Arffin and Bell (1997) further developed Lall's taxonomy of technological capabilities. In the framework technological capabilities are broadly categorised into three levels; basic, intermediate and advanced. The columns set out the main technological capabilities by technical function. Investment capabilities refer to generating change and managing its implementation during large investment projects. Largely they include activities related to both decision making and control along with preparation and implementation of projects. Production capabilities refer to generating and managing technical change in processes and production organisation, and in products. The other support function includes linkage capabilities; developing linkages and interaction with firms and institutions.

In this taxonomy, levels of technological activities are based on the distinction between the kind of knowledge and skills required to operate given technology and the kind of knowledge required to change technology (Bell and Pavitt, 1993). It distinguishes between the routine production activities and innovative technological capabilities; routine production capabilities are basic capabilities required to be in market. Basic level innovative capabilities include the ability to make minor adaptations to production and assimilate technology to the firm's environment. Intermediate innovative capabilities involve the ability to generate incremental technical change in product design, quality and production processes, it also includes ability to search and evaluate external sources of technology. Advanced innovative capabilities refer to the ability to generate new products and process innovations (table 3.1).

Basic level capabilities may permit only relatively minor and incremental contributions to change, but at the intermediate and advanced levels, technological capabilities may result in more substantial, novel and ambitious contributions to change (Bell and Pavit, 1995).

Lall (1992: 168) points out that this categorisation of capabilities is only indicative as it is difficult to judge whether a technical function is simple or complex, nor do the stages show a necessary sequence of learning. He further notes that the very nature of technological learning (accumulated experience of problem solving aided by external inputs or formal research effort) would seem to dictate that mastery would proceed from simpler to more difficult activities but different firms and different technologies adopt different sequences and the extent of inter firm differences in technological effort and mastery may very by industry, by size of firm or market; by level of development or by trade/ industrial strategies pursued. Different technologies differ greatly in their learning requirements

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involving different costs, risks, duration and linkages. This clearly shows the limitation of conceiving technological accumulating on broad stages and the need for more firm level research about processes involved in technological capability accumulation (Bell and Pavitt, 1995). It also signifies that this framework has limitations for its application to the firm level exploration of processes involved in technological capability accumulation as complexity of the technical function is subjective to individual task depending on the technology, firm, industry and market (Lall, 1987).

In addition Lall (1987) recognises that the 'classification has dealt strictly technical aspects of an enterprise; however organisational capabilities have to accompany technological ones'. Even though both the technological and organisational institutional factors are recognised as part of the technological capabilities, the interaction between both dimensions is a key issue but is hardly treated in developing countries literature.

3.2.3 Accumulation of technological capabilities in developing countries

In the last two decades, the literature on accumulation of technological capabilities in developing countries has emerged as a widely researched area and the following section briefly reviews some of the studies covering different aspects of technological capabilities. Earlier research on developing countries mostly covered technological adaptation (a movement along the frontier) than technological innovation (a movement of the frontier), based on the premise that adaptation of different technologies with which firms are not familiar would require same kind of technical effort as developing new techniques of their own. The ultimate achievement is to be a technologically mature firm and Bell, et al., (1984b) observes that the majority of infant industries in developing countries never achieve maturity because of their failure to build up adequate technological capabilities.

The impetus for the studies on developing countries lies in two large projects started in 1980s. In the early 1980s, the World Bank financed the project on 'the acquisition of technological capability' under the direction of Carl Dahlman and Larry Westphal. It covered four newly industrialised countries namely, India, South Korea, Brazil and Mexico. The studies mainly covered the manufacturing based industrial sectors like cement, iron and steel, pulp and paper and textiles. Each country was studied by different researchers, following a similar methodology and using identical questionnaires. The other study on developing countries was the Research programme in Science and Technology of IDB (Inter- American Development Bank) / ECLA (UN economic mission for Latin America). This included comparative research of metalworking industries from six Latin American countries.

The World Bank research project and studies of India by Lall (1987), South Korea by Westphal, et al., (1985) created and enriched the literature focusing on accumulation of technological capabilities in the developing countries. The various authors analyse how firms move from having the abilities to operate different production functions to being able to undertake innovative capabilities. These studies focused on the key issues related to capability accumulation like characteristics of learning processes, influence of technology transfer, intricacies involved in diffusion of technologies. According to Lall (1987) the process of technological change in developing countries is one of acquiring and improving on technological capabilities rather than of innovating at frontiers of knowledge. This process essentially consists of learning to use and improve production technologies that already exist in the advanced industrial countries. He further suggests that the enterprises deploying industrial technologies imported from advanced countries requires learning and conscious effort in the application of that technology to local needs.

Technological development is growth in a firm's ability – regardless of whether or not the firm is at the world technological frontiers - to innovate, copy or select the correct technology, and assimilate that technology. So technological development is achieved through growth in general ability to undertake this broad range of tasks or the ability to perform different types of technological activities. It illustrates that the process of technological change in developing countries is one of acquiring and improving on production capabilities rather than innovating at frontiers of knowledge. Dahlman, et al., (1987) suggest that firms in developing countries have accumulated technological capabilities in a particular sequence moving through definite stages. According to them building technological capabilities follows the sequence which generally starts with production capability and proceeds to investment and innovation capability. Therefore the learning hierarchy progresses from learning to produce, learning to produce efficiently, learning to improve production, learning to improve products and finally culminates in the development of new products. However Forbes and Wield (2002) question this learning hierarchy model, arguing that moving from imitation to innovation is not simply a case of one (process) giving way to another (product).

Some researchers focused on analysing the characteristics of the national systems of innovation (see for instance, Kim, 1993; 2000; Lundvall 1992; Nelson, 1993); the influence or features of macro economic trade policies like import substitution or export oriented that hamper or stimulate the technology capability accumulation at country and firm level (Nelson and Pack, 1999; Katz, 1987, 2000; Kim, 2000; Lall, 1987, 2000) and sources of international competitiveness (Haque, 1995; Katz, 1995). This research analyses the differences among economies, industries and firms, in which some introduced and

mastered new technologies while others encountered difficulties in technological development and international competitiveness. It also focuses on illustrating that at firm level there had been an 'indigenous technological effort' which has resulted in the accumulation of technological capabilities. But as Bell and Pavitt (1993) point out, the knowledge and institutional bases required for production capability and technological or innovative capability have become increasingly differentiated and increasing economies of scale have reduced learning opportunities for acquiring technological capabilities through production capabilities. As a result, accumulation of innovative technological capabilities has become increasingly uncoupled from the accumulation of production capability. This was reflected in studies of the industrialisation and catching up of firms in East Asian countries and the processes involved in the accumulation of innovative technological capabilities. The next section describes some of that literature.

3.2.3 Building of complex technological capabilities in newly industrialising countries

The transformation of South Korea and Taiwan into industrialised economies shifted the focus of research towards the acquisition of a more complex knowledge base required for innovative activity. Research into the process of catching up by the newly industrialising countries in South East Asia explains the stages involved in moving from acquiring foreign technology to building increasingly more innovative technological capabilities (see for instance Hobday ,1995; Kim,1997a; Kim, Lee and Lee, 1987; Amsden, 1989; Enos and Pack, 1988; Nakoaka, 1993; Pack and Weshphal,1986). Westphal et al., (1985) and Enos and Pack (1988) have demonstrated the importance of foreign technology collaboration agreements for functions such as training engineers and obtaining detailed blueprints in case of Korean firms for acquiring innovative capabilities. Hobday (1995) describes the rise up the value chain of firms from Taiwan in stages, from being original equipment manufacturers, to producing their own designs, and finally creating their own brands. He focuses on different learning strategies used by the firms to progressively assimilate foreign technology in order to develop design capabilities, to catch up and also leapfrog competitors at international level. Nakaoka (1993) describes successful cases of technology capability building from capital goods company from Korea, Taiwan and role of Japanese cooperation in it. He emphasises the role of domestic market and strategy related to international market in the learning process. Enos and Pack (1988) and Amsden (1989) focus on the accumulation of technological capabilities based on factor market determinants like skilled human resources. Nelson and Pack (1999) point out that South Korean or Taiwan success tells a story of cumulative learning, of climbing the ladder rung by rung, as it were. A high rate of investment in physical and human capital is also a part

of these stories, but only as handmaiden to the innovation and learning process within the firms. As firms climbed the ladder, and as the economies became increasingly sophisticated the need for detailed government diminished. So detailed government involvement both fell away, and was pushed away. They argue that the absorption or assimilation of increasingly modern technology and change in industrial structure were critical components of the transformation. Perez and Soete (1989) present a different perspective on technological capability building and suggest late industrialising countries, under very specific conditions, can bypass large parts of this cumulative process and leap frog to newly emerging complex technologies.

Lall (2000) based on experience of East Asian economies suggests that in terms of macro economic policies, export orientation has been conclusively shown to be a better strategy. He further adds that classical import substitution, with hapzard and open ended protection for all activities with no regard to efficiency, clearly breeds inefficiency and technological sloth. Trade intervention can be effective in stimulating technological learning if mounted with certain conditions like those of East Asian economies. The governments in these countries intervened both selectively and functionally in promoting technology development (Amsden, 1991; Pack and Westphal, 1986; Lall, 1996; Westphal, 2002). The presence of certain conditions for interventions like strong leadership commitment to competitiveness, flexibility in policy making, close interaction with industry and exposure to export competition to discipline both firms and government made the government intervention effective and successful (Lall, 1994; Stiglitz,1996; Westphal,2002).

In general, researchers studying newly industrialising economies analyses the deliberate learning strategy followed by these firms to sequence learning activities, and the role of the government interventions, trade policy and factor markets. These authors focuses on the accumulation of stocks of technological knowledge, and much less on the process of specialisation of knowledge bases and other firm specific issues like the coordination and integration mechanisms of knowledge across organisational boundaries. Bell and Pavitt (1995) point out that the rate at which a firm should proceed in accumulating capabilities, the level of sophistication and sequencing of accumulation among different functional areas will differ widely, suggesting the need for more research on strategies for accumulating technologies at firm level.

The next section reviews the studies which have focused on firm level research in developing countries.

3.3.4 Firm level process in accumulation of technological capabilities

Few studies have explored the firm level process involved in the accumulation of technological capabilities in developing countries or newly industrialising countries. Only some of the researchers like Kim and Kim, (1985), Kim (1997a), Duténit (2000) and Figueirdo (2003) have focused on organisational and managerial issues involved in the accumulation of technological capabilities and the development of innovative capabilities. Kim and Kim (1985) studied the patterns of innovative behaviour in Korean firms and showed the key role of informal mechanisms in transferring important technology from advanced countries to newly industrialising countries.

Kim (1998, 1997a, 1999) introduced a new framework to analyse the process of building innovative and complex capabilities in Korean firms, focusing on role of organisational factors in the process of knowledge creation. He explores the process of creation of new knowledge at international level instead of the concern for using existing knowledge that distinguishes most of the developing countries literature. Using the case study methodology, he shows the sequential patterns of learning in two South Korean firms namely, Samsung and Hyundai. These studies show that these South Korean firms not only followed a deliberate and persistent technology strategy, which gradually changed as the firm acquired technological capabilities from creative imitation to innovation. Top management in the firm constructed a crisis to expedite the learning processes within the firms and implemented an active management of dynamic learning. Firms managed the learning process in such a way that different internal components of a knowledge system were articulated to strengthen the knowledge building process. However according to Kim (1997a) two critical enabling factors that set Korean firms apart are the Korean government and the Korean people. He particularly stresses that successful technological learning requires an effective national innovation system. The focus on the national system of innovation and the Korean worker in research makes the external condition more crucial factor for building firm level technological capabilities than internal factors. At the firm level Kim focuses on crisis construction as an important mechanism for discontinuous or dynamic learning but other supportive mechanisms of managing knowledge which play an important and essential role have not brought into focus. The other firm level study focused on Vitro, a Mexican firm in glass industry by Dutrénit (2000) concentrates on these issues. She analyses the mechanisms of managing knowledge while studying the transition of a Mexican firm from 'early stage of accumulation of minimum knowledge levels of innovative capability to the management of knowledge as a strategic asset'. She builds on Kim's (1999) theoretical framework and focuses on processes involved in the conversion of individual into organisational learning, the coordination of learning,

knowledge integration and knowledge creation. Research develops the three different stages of building technological capabilities. In the first stage, the minimum essential knowledge base is built, while in the second stage the minimum essential knowledge base is transformed into strategic capabilities. The third stage firm has been able to build up strategic capabilities and is able to nurture and renew them continuously. The study shows that transition process in the Mexican firm was truncated because the support and the resources were unstable over these stages of different innovation strategies applied by firm. She further explains that the firm pursued a pioneer and fast follower strategy in different areas at the same time. The knowledge management was not considered in a systematic approach and the technological knowledge was not distributed across other organisational units of firm pointing out the importance of organisational factors like coordination and integration of different knowledge bases and difficulties in managing them. However, while analysing the transition of the knowledge management mechanisms in the firm this research neglects the influence of constituents of external environment which as Kim's research shows affect the firm's learning mechanism. A nation's capability to foster and manage technological change is crucial to its firms' ability to survive and grow in the international marketplace (Bell and Pavitt, 1995).

Even though the research on technological capabilities in firms from developing countries covers a broad range of industries, there are no studies concerning highly knowledge intensive science based industries like pharmaceuticals. Different technologies involve different breadth of skills and knowledge, with some needing a relatively narrow range of specialisation and others a wide range. The learning processes by which those resources are accumulated are complex and specialised. The process of technological accumulation and change in science based sectors like pharmaceuticals is more difficult and demanding as it requires highly professionalized and specialised technological activities in R&D laboratories and other similar institutions. Also large firms at technological frontiers that dominate these sectors develop and control significant proportions of both their product and process technology, and are reluctant to give easy access to this major source of competitive advantage to firms which are outside the technological perimeters. In these sectors large firms conduct most of their technological activities at home or in other developed countries, and prefer direct investment to licensing when producing abroad. The learning process by technological capabilities are built in science based industries is far more complex and specialised and therefore in context of developing countries needs more attention.

The review of developing countries literature suggests the following important points:

A. One of the concerns of the DCL was to illustrate at the firm level as well as country level that there had been an indigenous technological effort which had resulted in the accumulation of technological capabilities. It shows that firms build technological capabilities through learning processes - firms learn over time, accumulate technological knowledge, and can progressively undertake new activities and acquire new capabilities.

B. In general the focus of the DCL has been on the learning processes to establish a base of technological knowledge that did not previously exist, as opposed to renewing the accumulated knowledge base or using that knowledge base in a different way. Bell and Pavitt (1993) point out that change generating capabilities have become increasingly complex and specialised as they have become increasingly more differentiated from the capabilities required to use them and have become increasingly differentiated.

C. The variability of technological accumulation patterns suggests the need for care and clarity in choosing specific strategies for accumulating technologies at the firm level. Although there is growing body of knowledge concerning the technological strategies of the firms in the industrialised countries that have already accumulated some advanced levels of capabilities, there are few guidelines for firms to follow in designing strategies to move from more basic levels to these advanced capabilities (Bell and Pavitt, 1995).

To summarise, the firm level research of technological capability renewal and development in developing countries needs more attention as technological change is mostly localised at the firm level. Therefore understanding of the dynamic process of technological learning at firm level is most essential as formal education and training in institutions outside industry can only provide essential bases of skill. This has to be augmented by learning within firms, and of which 'learning by doing' provides only part of what is needed (Bell and Pavitt, 1993).

The next section reviews the strategic management literature focused on the processes involved in capabilities transformation and creation in firms from advanced countries.

3.3 Renewing capabilities in the strategic management Literature

This section reviews the strategic management literature concerned with maintaining, nurturing and renewing core capabilities/ competencies by most innovative firms competing at the technological frontiers in advanced countries. It presents the different

concepts in strategic management literature used to analyse the rebuilding or renewal of distinctive capabilities. It points out that the research concerned with firm level studies of learning and capability building is focused on the most innovative firms competing at the technological frontier. However this review of strategic management literature also shows the limited insights into processes involved in building the basic core or distinctive capabilities. This literature fails to answer the questions of how do successful firms get to the point where they have superior resources and knowledge? (Helfat and Raubitschek, 2000).

3.3.1 Firm capabilities and strategic management

Strategic management literature is mainly concerned with the patterns of actions and resource deployments that a firm undertake to achieve its objectives while simultaneously adapting to changing environmental conditions. This adaptation occurs through the process of matching internal capabilities with external opportunities and threats. Grant (1991) defines capabilities as what firm can do as a result of teams working together, although he further adds capabilities is not simply a matter of assembling a team of resource. According to Grant (1991) capabilities involve complex patterns of coordination between people and between people and other resources.

However in recent decades accelerating changes in markets, competition and technology are giving rise to more challenging questions for firms and as a result a large amount of research has been focused on examining how firms can align or adapt themselves to those changes and maintain competitive advantage. The strategy management literature points out that in an environment of increasing change and uncertainty, accumulated distinctive competencies or capabilities gives firms the competitive advantage (Grant, 1991; Leonard – Barton, 1995; Pavitt, 1991; Teece et al, 1997; Henderson and Cockburn, 1994; Nelson and Winter, 1982). In the case of a rapidly changing environment, a firm's capability to adapt to new circumstances and innovate rather than innovation per se, improves the chances of its long term success (Harris and Mowery, 2001). Central to this perspective has been the prescribed role for the firm as the developer of distinctive competencies – that is, firms are encouraged to innovate by searching out new resources, or new ways of using existing resources, as the basis for future organisational rents (Galunic and Rodan, 1998). This research suggests that firms compete on the basis of distinctive competencies or capabilities that are accumulated over time (Leonard – Barton, 1992; Prahalad and Hamel, 1990; Teece et al., 1997; Nelson and Winter, 1982, Pavitt, 1991). Distinctive competencies refer to the unique capabilities possessed by the firm which enable it to do some things 'better' than its competitor.

The unit of analysis in this research is firm, and insights are based on firm level research into sources of sustainable competitive advantage. It is built up on the idea of Penrose (1959) that the profitability and growth of a firm should be understood in terms of its possession and development of unique resources and Polanyi's (1966) work about tacit knowledge. This literature share the idea that knowledge allows the creation of capabilities and those capabilities determine the ability to do things (Leonard – Barton, 1992; Prahalad and Hamel, 1990; Teece, et al., 1997).

According to Dosi et al., (2000) capabilities involve organising activity and the exercise of capability is typically repetitious in substantial part, and routines represent the chunks of organised activity with a repetitive character. Organisational routines are regular predictable patterns of activity which are made up of a sequence of coordinated actions by individuals. Therefore, a capability is, in essence, a routine, or a number of interacting routines (Grant, 1991). This concept of routines as the basis of capabilities is based on the evolutionary economic perspective developed by Nelson and Winter (1982). They defined the firm as a repository of knowledge, dependent on its past history and the firm stores the knowledge generated by learning in organisational routines. However routines are not only building blocks of capabilities; knowing the job involves knowing things that are relational, involving other participants and organisation specific factors (Nelson and Winter, 1982). The major function of organisational routines is coordinating the skills of organisation, that is, of turning that collectivity of skills to useful effect (Dosi et al., 2000). The knowledge embedded in routines cannot be fully captured in codified form, it has a tacit dimension; some of the knowledge required to do a job is skill-like and can be learned only through experience in the specific organisation. Therefore several routines are seen as the source of distinctiveness and therefore competitiveness of the firm.

Building on the tacit knowledge component from evolutionary economics perspective but rooted in resource and capability view, Prahalad and Hamel (1990) introduced the notion of core competencies as the source of a firm's advantage in a changing environment. According to them core competencies are the collective learning in the organisation, especially how to coordinate diverse production skills and integrate multiple streams of technologies. Comparing large corporations to a tree, Prahalad and Hamel, (1990) suggest that core competence is the root system that provides nourishment, sustenance and stability. The pattern of internal coordination and learning is difficult for competitors to imitate, as it has a tacit component and this tacit component of core competencies creates competitive advantage for firms. They further point out that in the long run the firm's competitiveness derives from its ability to build core competencies at lower cost and faster than competitors. And so the firm's long term success lies in its ability to consolidate

corporation wide technologies and production skills into competencies that empower individuals businesses to adapt quickly to changing opportunities.

Prahalad and Hamel (1990) explain that at organisational level core competence involves communication and deep commitment of many people working at different levels across organisational boundaries. At technological levels core competencies exists, as a set of technological field (e.g. Optic media in Philips) or as a capacity to do something with technology or to apply capacity to other fields (e.g. capacity to miniaturise in Sony or 3M's capacity to substrate, coatings and adhesives and various ways to combine them to develop different products). This explanation implies that core competence cover both, technological and organisational dimension, however the empirical definition of core competencies suggests that it is conceptually more focused on the technological dimensions.

Focusing on core competency perspective Leonard – Barton (1992: 114) suggests that a core capability is an 'interrelated, interdependent knowledge system'. This knowledge system comprises four interdependent dimensions:

1. employee knowledge and skills,
2. technical systems,
3. managerial systems, and
4. values and norms associated with the process of knowledge creation and control.

All four dimensions of core capabilities reflect accumulated behaviours and beliefs based on early corporate successes. It is not possible to copy a system and copying an isolated mechanisms and fitting them into other knowledge systems does not necessary generate same results. The main advantage of core capabilities lies in this unique system or linkages, which is not easily imitated by other competitors. Therefore Leonard – Barton (1992) points out that as bodies of knowledge, core capabilities cannot be managed in the same way as the tangible assets of the firm. However Patel and Pavitt (1994, 2000) based on a patent data study of large firms suggest that it is difficult to define a firm's technological competencies in terms of a few fields of excellence. According to them. firms operating in sectors like automobiles or aircraft which involve making and improving complex production systems, require a broad range of technological competencies that enable them to stimulate and integrate technological improvements by their suppliers of materials, components, subsystems and production equipment. This technical interdependence means that the notion of 'focus' and 'make or buy', applied in production and marketing activities does not work in relation to technological competencies. They argue that firms are typically active in many technical fields and have substantial

technological competencies outside their core areas and conventional analysis neglects these important background competencies in its focus on distinctive or core competencies.

Leonard – Barton (1995) in similar vein suggests that the successful large organisations derives competitive strength from its excellence in a small number of capabilities clusters where it can sustain leadership position over time through effective management of those clustered capabilities. She defines three types of technological capabilities that contribute to creating a sustainable advantage: core, enabling and supplemental technological capabilities. Core technological capabilities are those capabilities that distinguish firm competitively, and built up over time and can not be imitated. Enabling capabilities are those capabilities which do not give a particular competitive advantage but are necessary to a firm as minimum basis for meeting the competition, such as world – class manufacturing and supplemental capabilities only add value to core capabilities but could be imitated like particular distribution channels or strong but not unique packaging design skills.

Henderson and Clark (1990) illustrate the cluster of capabilities at product level by distinguishing between types of knowledge or capabilities involved in product development. They suggest that an individual product consists of multiple components, each of which has separate 'component knowledge' consisting of basic knowledge underlying the component representing the knowledge of specialist elements in an organisation. In addition to that product system requires architectural knowledge or knowledge about the ways in which the components of the system are integrated and linked together into coherent whole and which is embedded in organisational structure, problem solving strategies and information processing procedures of the established firms. In the case of technological change the management of organisational renewal should to a large extent be aimed at creating new architectural knowledge, which is a matter of reconfiguring existing component knowledge (Henderson and Clark, 1990; DeBoer et al., 1999). Bogner and Thomas (1994) suggest that researchers have often perceived core competence as a static concept implying that core competency approach does not adequately explain how and why certain firms have competitive advantage in situations of rapid and unpredictable change. In defining a core competence or in describing a competitor's competence at any point in time, a description is often used which implies a stable condition or relationship.

In markets where the competitive landscape is continuously shifting, dynamic capabilities become the source of competitive advantage (Teece et al., 1997) where dynamic capabilities' refer to the 'firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments'. Building upon the

resourced based approach, this perspective has stressed both the dynamic dimension of the capability building process and the role of organisational capabilities in that process.

Dynamic capabilities are defined as 'the subset of competence/ capabilities which allow the firm to create new products and processes and respond to changing market circumstances (Teece et al., 1997). These capabilities are rooted in high performance routines operating inside in the firm, embedded in firm's processes, and conditioned by its history. According to Teece and Pisano (1994) the term 'dynamic' represents the capacity of firm to renew competencies so as to achieve congruence with changing business environments and the term 'capabilities' emphasises the role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organisational skills, resources, and functional competences to match the requirements of a changing environment. The firm specific processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources - which are key in gaining and sustaining competitive advantage in industries facing rapid technological and market changes, forms base of dynamic capabilities (Einsenhardt and Martin, 2000). Therefore firm's dynamic capabilities are determined by three classes of factors:

a. processes – managerial and organisational routines; way things are done in the firm

b. positions – current endowments of technology, customer base, and suppliers

c. paths – available strategic alternatives.

Dynamic capabilities thus are the organisational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, spilt, evolve or die (Eisenhardt and Martin, 2000). The dynamic focus of this perspective is based on stressing the importance of continually developing new capabilities as well as exploiting old ones in the context of a shifting environment.

Extending on the Eisenhardt and Martin's (2000) work on dynamic capabilities, Zahra and Gorge (2002) shows that the absorptive capacity could be a primary source of creating and sustaining a competitive advantage for firms in a dynamic market.

Dosi et al., (2000) point out that the concepts of core competence and dynamic capabilities point in the same direction broadly concerned with the firm's ability to carry off the balancing act between the continuity and change in its capabilities and to do so in a competitively effective fashion. The discussion of dynamic capabilities. has however both in broader scope and more explicit in its treatment of the details of the capabilities and change than the core competence discussion. Teece and Pisano (1994) develop the foundation of dynamic capabilities which was further elaborated by other researchers like Eisenhardt and Martin, 2000; Henderson and Cockburn, 1994; Rosenbloom, 2000, Iansiti and Clark, 1994; Helfat and Raubitschek, 2000,).

Rosenbloom (2000) studied the issue of dynamic capabilities by focusing on NCR's (National Cash Register Company) efforts in adapting to revolutionary technological change in its major line of business. He traces the efforts of NCR to adapt to the introduction of electronics and 'waves of change' in the business equipment industry. After a long unsuccessful period of evolutionary change, NCR regained its market leadership and Rosenbloom identified prominent role of top management within NCR, among several factors that led to NCR's resurgence. As Rosenbloom (2000) states: 'individual leadership…may well be a central element of dynamic capability'.

Eisenhardt and Martin (2000) suggest that extensive empirical research has identified specific routines which create dynamic capabilities. They suggest that some researchers identified the capability for integration as dynamic organisational capability, while others focused on reconfiguration of resources within firms as the basis of dynamic capabilities. Still other researchers focused on knowledge creation routines as whereby managers and others build new thinking in the firm, a particularly crucial dynamic capability and essential one for effective strategy and performance. Eisenhardt and Martin (2000) provide evidence that dynamic capabilities consists of less structured and less complex routines in high velocity markets.

Many researchers have focused on the concept of knowledge integration as base of firm's dynamic capability (see for instance Clark and Fujimoto, 1990; Iansiti and Clark, 1994; Henderson, 1994). Based on Dosi and Marengo's (1993) argument that problem solving activities, are essence of competence building processes and the basic unit of knowledge creation, Iansiti and Clark (1994) suggest that the capacity to integrate diverse knowledge bases through problem solving is the basic foundation of knowledge building in an organisation and is therefore a critical driver of dynamic performance. Therefore they considered the capability for integration as basis for the process of capability building and renewal. Similarly, Clark and Fujimoto (1990) points out that in a competitive environment, integration is the underlying source of superior performance and in such cases integration is seen as specifically organisation specific capability. Clark and Wheelwright (1995) suggest that effective product and process development requires the integration of specialised capabilities and it is specially challenging in large firms with strong functional groups, extensive specialisation, large numbers of people, and multiple, ongoing operating pressure.

Iansiti and Clark (1994) analysed the internal integration across internal boundaries of the firms and the external integration across firm boundaries. They define internal integration as the capacity for extensive coordination between different specialised subunits within the organisation while external integration is divided into sub dimensions; customer

integration and technology integration. Henderson and Cockburn (1994) use same approach, but they analyse integration in terms of internal and external organisational boundaries as well as technological boundaries focusing on the organisational arrangements that allow the integration of different knowledge bases and creation of new technological competence.

Henderson and Cockburn (1994) distinguish firm's capabilities to transform its resources on two dimensions: component capabilities and integrative capabilities, where integrative capabilities refer to the ability of a firm to use resources and component capabilities in new or flexible ways to support organisational renewal. They point out that the ability to integrate knowledge both across the boundaries of firm and across disciplines and product areas within the firm is an important source of strategic advantage.

One other important idea in this area is referred to as combinative capabilities by Kogut and Zander (1992), concerned with the firm's capabilities of combining new knowledge with deeply accumulated knowledge. In combinative capabilities the emphasis is on the firm's ability to handle change by transforming old capabilities to produce new competencies by recombining existing capabilities and other knowledge. Two points about the nature of this transformation are emphasised:

1) that the firms produces new capabilities by recombining existing capabilities and other knowledge

2) that the ability of the firm to do this is affected by the organising principles guiding its operations – principals that include matters of formal structure but, more importantly internal social relations shaped in part by difference in the knowledge bases of individual and groups within the firm.

Different researchers in strategic management literature have used a number of concepts, however many of them share a basic principle. Henderson and Cockburn (1994) suggests that their concept of architectural competence, representing the firm's integrative capability is similar to the notions of combinative capabilities (Kogut and Zander, 1992), managerial systems and values and norms (Leonard – Barton, 1992), dynamic capabilities (Teece et al., 1997). For instance Teece et al., (1997) suggests that 'core competencies, as raised by Prahalad and Hamel, are identical to our concept of capabilities and resources.' Therefore as Dodgson (1993) suggests that theoretically different concepts like firm specific competences (Pavitt, 1991); dynamic capabilities (Teece and Pisano, 1994) and core competencies (Prahlad and Hamel, 1990) share similarity between them. They all define organisational uniqueness by knowledge bases and the processes of acquisition, articulation and enhancement of the knowledge embedded in firms historically developed contexts over which it has control.

They use different approaches to express common idea: the uniqueness of firm's knowledge and learning, which has difficult to imitate strong tacit component.

To sum up, this review of strategic management literature shows that despite the differences between the concepts of capabilities, there is some consensus that the process of maintaining, nurturing and renewing core capabilities or competencies requires continual reconfiguration of a bundle of resources through learning processes. Knowledge is foundation of the capability and therefore management of knowledge has become a key organisational issue in nurturing and renewing or reconfiguring of capabilities. Knowledge creating activities like sharing knowledge within the organisation and integration of knowledge across organisational boundaries is seen as the basis on which firm create, sustain and rebuild technological capabilities (Leonard – Barton, 1992; Dosi and Marengo, 1993; Prahalad and Hamel, 1990; Teece, et al., 1997). Specifically as Leonard – Barton (1995) points out, it is through systematic decision making and actions, both routine and strategic, core and technological capabilities can be built and changed, therefore as firms compete on the basis of their ability to create and utilise knowledge, the management of knowledge has becomes a central issue. This focus of competence based theories of the firm on knowledge and learning highlights the dynamic and evolutionary characteristics of firm.

However some researchers have criticised the treatment of knowledge in competence based approaches as 'too objective and too linear'. These researchers suggest that competence based approach tends to objectify knowledge within organisations, abstracting it from its situated and socially constructed origins. Its managerialist interpretation produces too linear a view of the causal relationships between organisational knowledge and competitive performance (Scarbrough, 1998; Tsoukas, 1996). Scarbrough (1998) suggests that the competencies approach fails to follow the logic of its own argument as far as organisational appropriation of knowledge is concerned. He argues that the competencies based approaches neglects socially embedded qualities of organisational knowledge. Contrasting it with the organisational theorist approach to knowledge. Scarbrough (1998) argues that organisational theorist has developed an appreciation of organisational knowledge that reflects processes of social construction and the social relations in which knowledge is embedded, ranging from inter organisational networks and occupational communities. Therefore the treatment of organisational knowledge in competence based view of firm neglects the importance of wider institutional context of firm's strategic development and which have critical implication for formation and deployment of knowledge in organisations.

3.4 Renewal of capabilities to create knowledge for innovation in Indian pharmaceutical firms

The descriptions of the main issues of both bodies of literature while complementing each other, points out some differences in the approach to technological capabilities.

A. SML has focused on technological as well as organisational dimensions of capability creation. It is perhaps more concerned about organisational issues involved in the creation of knowledge to maintain and renew the core capabilities. As Pavitt, (1998) points out the lack of technological knowledge is rarely cause of innovation failure in large firms based in advanced countries and problems are more organisational. However for firms in developing countries availability and access to technological knowledge is an equally bigger issue and it is reflected in literature on the developing countries which is mostly focused technical knowledge dimension of the building up of technological capabilities.

B. DCL focuses on long term process of technological capability accumulation in firms from developing countries and SML focuses on the maintaining and renewing of knowledge. Most of the firm level research regarding learning and capability building concerned with sustaining, deepening and renewing their existing innovative capabilities is focused on most innovative firms competing at the technological frontier in advanced countries. Therefore there is a flourishing literature available on the firm specific factors that affect the success and failure of innovation in advanced countries, but there is no literature of equivalent scope and depth for developing countries (Bell and Pavitt, 1995).

With the advent of globalisation firms in the developing countries are going through their battles of survival and reinvention. Although the uniformation of trade laws due to world trade agreements means that a firm that is a new entrant into a US market or other advanced country experiences challenges not unlike those of newcomer located in a newly industrialising country. In rapidly changing globalise world the challenge for firms is to find new ways of doing things (Teece, 2000). However the main difference is in the object of analysis, the firm in a developing country and its external environment as opposed to a global world player. In a developing country, knowledge of traditional, stable and simple technologies may not be a good base from which to learn how to master modern technologies. Firms may not know how to build up the necessary capabilities – learning itself has to be learned (Stiglitz, 1987). In developing countries firms compete on the basis of production capabilities, largely acquired from elsewhere and reinforced by basic to intermediate technological capabilities related to a simple knowledge base. The transition

from intermediate innovative capabilities to advanced innovative capabilities represents movement from simple knowledge base to complex knowledge base. It represents the movement towards competing with the technological frontier firms on the basis of knowledge bases and capabilities. This transition process and the specific firm level processes involved in such transformation, is the focus of this research.

Therefore, as the review points out, neither developing countries literature nor strategic management literature has paid adequate attention to this particular issue. However as Teece (2000) suggests, the institutional contexts may be different in developing or newly industrialised countries compare to advanced countries but the basic process of learning and advancement as a response to change are applicable to them as well. Therefore these two literatures provide some ideas that are drawn on to develop the theoretical framework that is used in this research.

3.5 Summary

This chapter discussed the literature focused on capability creation in firms from advanced and developing countries. This review shows that the transformation happening in Indian pharmaceutical firms has not been explored by both strands of literature so far and this research aims to fill that gap. This research analyses the long term historical process of building technological capabilities in the Indian pharmaceutical industry. But it specifically focuses on the firm level processes involved in discontinuous learning in the Indian pharmaceutical industry as a response to change in external environment and the firm level differences in learning process.

The next chapter reviews some of the literature examining the emergence of knowledge as strategic resource and its role in creating innovative capabilities. It also presents the theoretical framework used of exploring the capabilities transformation.

Chapter 4

THEORETICAL FRAMEWORK

4.1 Introduction

This chapter presents the theoretical framework used in this research for exploring the 'firm level processes' involved in the development of knowledge creation capability for innovation as a response to change in the external environment. It is based on the absorptive capability concept and builds on earlier frameworks which have focused on organisational knowledge creation. It draws on the strategic management and organisational theory literature focused on knowledge, learning and innovation.

The review of strategic management literature suggests that knowledge is the foundation of capability and so management of knowledge facilitates the renewal of existing capabilities and helps to develop new competencies. Therefore in last decade knowledge based theory of the firm has emerged highlighting 'managing knowledge' as a key organisational issue in the nurturing and renewing or reconfiguring of core competencies (Grant, 1996a; Nonaka, 1994; Kogut and Zander, 1992). Spender and Grant (1996) point out that there is growing belief among managers that understanding the issues related to organisational knowledge and learning has a central role in firms' responses to change. Kim (1997a) showing the key role of learning in creating and managing knowledge defines organisational learning as a dynamic process of acquiring, assimilating and applying new knowledge. Other researchers like Tsoukas and Mylonopolous (2004) focusing on the interdependencies between knowledge, capability and learning, suggest that organisational knowledge, learning and capabilities form a triangle: the ongoing development of organisational knowledge is or can be a dynamic capability that leads to continuous organisational learning and further development of innovative knowledge assets. Zollo and Winter (2002) argue that dynamic capabilities are shaped by the co-evolution of learning mechanisms involved in knowledge accumulation, knowledge articulation and knowledge codification. Tsoukas and Mylonopolous (2004) summarising the relationship between capability, knowledge and learning suggest that a 'learning firm' is a firm that has developed the capability to integrate, communicate and create knowledge on an ongoing basis. Tidd (2000) presents a framework to link these different but interdependent concepts of knowledge, learning and innovation with core or strategic competencies of firms.

However in the case of technological advances or fundamental regulatory reforms, firms have to develop new competencies through revolutionary change or discontinuous learning (Tushman and O'Reilly III, 1996). The capability of the firm to maintain, nurture and renew or reconfigure technological capabilities is based on the ability of the firm to develop new competencies by acquiring new knowledge and integrating or combining it with existing knowledge bases (Kogut and Zander, 1992, Teece, et al., 1997; Cohen and Levinthal, 1990). In a similar vein Henderson and Clark, (1990) suggest that such change and adoption involves not only learning new components of knowledge but also the new linkages between the components and so it requires reconfiguration of existing systems of linkages in a new way. Therefore in an uncertain environment, the ability of the firm to develop new competencies depends upon the firm's absorptive capacity; the firm's ability to evaluate, assimilate and apply outside knowledge (Cohen and Levinthal, 1990) and which is viewed as function of two separate but interrelated dimensions:

a. the firm's ability to acquire the knowledge relevant to the new technological paradigm and

b. firm's ability to integrate external knowledge into existing capabilities.

But the organisational learning literature (Levitt and March, 1988; Cohen and Levinthal, 1990) and the evolutionary economics perspective on innovation (Nelson and Winter, 1982; Pavitt, 2002) suggest that a firm's absorptive capacity or learning capability tends to be cumulative and path dependent. The prior knowledge base provides the base on which firms develop the capabilities to cope with new technological change or new external environment. It provides firms an ability to exploit external knowledge and therefore forms the critical component of innovative capabilities. So the absorption of new knowledge will depend on the accumulated stock of past capabilities or knowledge and mechanisms of knowledge transfer (Cohen and Levinthal, 1990).

The theoretical framework is thus based on the combination of these different conceptual perspectives. To summarise briefly, it explores the social processes or mechanisms used for knowledge acquisition, transfer, assimilation, and application in innovative Indian pharmaceutical firms. It also explores the relevance of prior knowledge base in terms of its usefulness in a new environment and how firms have built it.

This chapter presents the theoretical framework based on absorptive capacity concept and explain its rationale with the review of literature focused on knowledge, learning and innovation. Section 4.2 reviews the literature on knowledge, learning and innovation. It shows the role of knowledge in developing capabilities for innovation and processes involved in creating knowledge like organisational learning, communicating and remembering. Section 4.3 looks at transformation in large pharmaceutical firms as a

response to biotechnological change. The processes used by large pharmaceutical firms for discontinuous learning guides in operationalising the theoretical framework. Section 4.4 presents the theoretical framework used for exploring the discontinuous learning in Indian pharmaceutical firms. Section 4.5 concludes the chapter.

4.2 Knowledge, Learning and innovation

4.2.1 Managing knowledge within the organisation

The emergent theme in the strategy literature is the idea that the most distinctive role of the business system is the way it brings knowledge to bear on superior firm performance and is discussed under the heading of knowledge based theory of the firm.

The knowledge based view argues that firms exist as they provide ideal platform for creation, transfer and application of knowledge (Grant, 1996a, Nonaka, 1994, Spender, 1996a; Tsoukas, 1996). It sees firm as a knowledge system or bundle of knowledge assets and effective management of which affords firms competitive advantage (Grant, 1996a; Spender, 1998). There is increasing understanding that knowledge allows the creation of the capability and that determines the ability to do things (Grant, 1996a; Henderson and Cockburn, 1994; Leonard- Barton, 1995) and so the manner of knowing or learning is as important as what should be known (Spender and Grant, 1996). Knowledge or knowledge assets are conceived as know-how embedded in the organisation's activities and these knowledge assets are deeply rooted into firms historically developed context. Therefore these assets are idiosyncratically complex and dynamic and so unique in nature (Grant 1996b; Spender, 1996a). According to Tsouskas and Mylonopoulos (2004) the knowledge based perspective on organisation links two traditionally different domains: the skills that sustain organisational learning and a firm's competitive advantage through idiosyncratic capabilities.

One of the key contributions towards the emergence of focus on knowledge and its strategic role is studies of organisational knowledge creation in Japan by Nonaka and Takeuichi. Building on the distinction between tacit and explicit knowledge proposed by Polanyi (1966) and linking the resource and capability view of the firm with organisational learning literature, Nonaka and Takeuichi (1995) developed the model of the various ways in which organisations create knowledge. Based on the idea that knowledge is product of the learning, they focused on knowledge. The organisational knowledge creation is seen as a capability of the organisation. The knowledge creation model relates the tacit and explicit knowledge with individual and organisational knowledge and suggests a style of management and organisational structure for best managing the knowledge creation process. Nonaka and Takeuchi (1995) postulate that the organisation creates new

knowledge through interactions between tacit and explicit knowledge, and through a dynamic process of conversion of knowledge between these two dimensions of knowledge. Through this 'social conversion' process tacit and explicit knowledge expands in terms of both quality and quantity. Knowledge is transferred from individuals to a larger group of individuals in a spiralling process. It follows from the proposition that, although tacit knowledge is initially locked up in the heads of the individuals, shared experiences allows individuals to project themselves into each other's thinking processes.

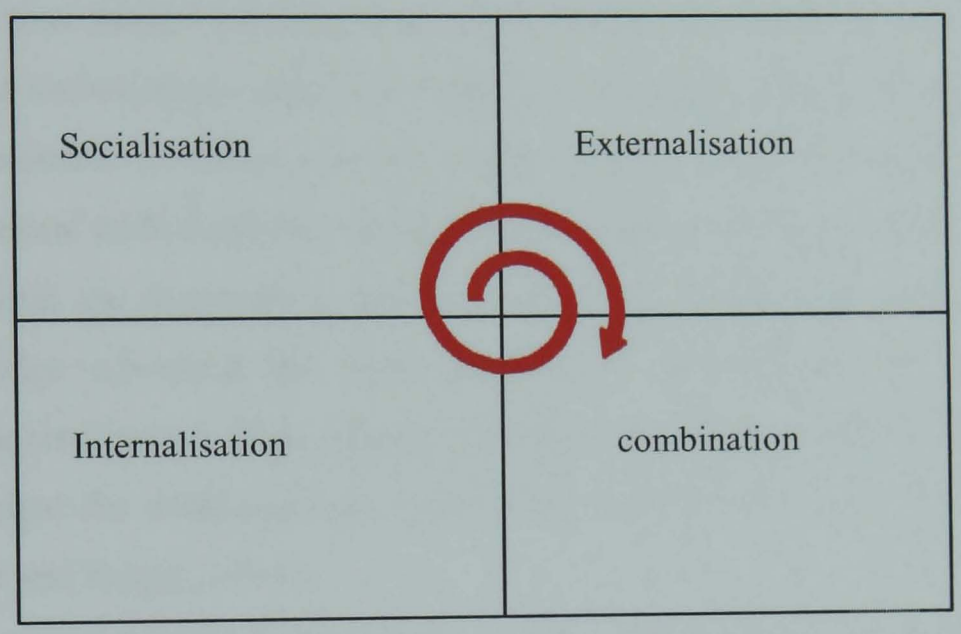


Fig 4.1: SECI spiral

According to Nonaka et al.,(2000b) knowledge is created through the SECI spiral which goes through four modes of conversion between tacit and explicit knowledge (Fig 4.1):

1. Socialisation (from tacit knowledge to tacit knowledge);
2. Externalisation (from tacit knowledge to explicit knowledge);
3. Combination (from explicit knowledge to explicit knowledge) and
4. Internalisation (from explicit knowledge to tacit knowledge).

Socialisation involves transfer from tacit to tacit and is a process of sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills. A key to acquiring tacit knowledge is experience and without some form of shared experience, it is extremely difficult for one person to transfer knowledge to another person. Externalisation is a process of articulating tacit knowledge into explicit concepts. It is a quintessential knowledge creation process in that tacit knowledge becomes explicit, taking the shapes of metaphors, analogies, concepts, hypotheses or models. Combination is a process of systemizing concepts into a knowledge system and involves combining different bodies of explicit knowledge. In business context the combination mode of knowledge conversion is most often seen when middle managers break down and operationalise

corporate visions, business concepts, or product concepts. Internalisation is a process of embodying explicit knowledge into tacit knowledge. It is closely related to 'learning by doing'. When experiences through socialisation, externalisation, and combination are internalised into individuals' tacit knowledge bases in the form of shared mental models or technical know-how, they become valuable assets.

Central to the Nonaka and Takeuchi's knowledge conversion model and in other works related to managing knowledge is Michael Polayni's distinction between tacit and explicit knowledge. Tacit knowledge is subjective and experimental and hard to formalise. Belief, perspective, mental models, ideas and ideals are some of the examples of tacit knowledge. Explicit knowledge is objective, rational knowledge and can be expressed in forms such as data, scientific formulas, specific actions and manuals. This classic distinction is then used to elaborate additional knowledge dichotomies, for example canonical vs. non canonical, procedural vs. declarative, and know-how vs know what. The different typologies of knowledge advanced the understanding of organisational knowledge by showing its multifaceted nature. This distinction between different types of knowledge is the reason often cited for distinguishing knowledge from other resources (Kogut and Zander 1992; Zander and Kogut, 1995).

Nonaka et al., (2000a) also points out that other important feature of knowledge; context specificity; without context, knowledge is just information. Therefore knowledge creating processes are necessarily context specific, in terms of who participates and how they participate in the process.

This 'SECI' model perspective suggests that organisational knowledge creation takes place between three levels: individual, team and organisation. The spiral represents the dynamic process, starting at the individual level and expanding as it moves through communities of interaction that transcend sectional, departmental, divisional and even organisational boundaries (Nonaka and Konno, 1998).

Cook and Brown (1999) present the different model for organisational knowledge creation albeit based on different types of knowledge (fig 4.2). They point out that tacit and explicit knowledge are two different types of knowledge which complement each other but do not convert into each other. They further argue that there is fundamental discontinuity between individual and group knowledge. They propose that individuals and groups can each possess explicit knowledge and tacit knowledge and thereby giving four different categories of knowledge. However all four knowledge types can be mutually enabling in the pursuit of purposeful activity or 'active process of knowing'. New knowledge is generated as different knowledge types 'dance' together in course of doing something.

	Individual	Group
Explicit	Concepts	stories
Tacit	Skills	Genres

Fig 4.2: Four forms of knowledge (Cook and Brown, 1999)

Continuing with different types of knowledge and ways of knowing, Spender (1996b: 74) sketches a theory of the firm as a system processing different kinds of knowledge and generating common knowledge (Fig 4.3). He suggests that knowledge, learning and memory form the interdependent parts of organisational system and are influenced by particular types of knowledge. The firm comprises of four distinct types of knowledge: conscious (explicit knowledge held by the individual), objectified (explicit knowledge held by the organisation), automatic (preconscious individual knowledge) and collective (highly context dependent knowledge which is manifested in the practice of an organisation) and each imply different learning and memory processes. These different types of knowledge interact dialectically to form an organic system with knowledge both at the level of system and at the level of individuals it embraces.

	Individual	**Social**
Explicit	**Conscious**	**Objectified**
Implicit	**Automatic**	**Collective**

Fig.4.3: Different types of knowledge (Source: Spender, 1996b)

These perspectives propose that organisations have different types of knowledge and that identifying and examining these will lead to more effective means for generating, sharing and managing knowledge in organisations. However, Tsouskas (1996) characterised such perspectives as 'taxonomic' and argues that typologies of knowledge are marked by 'formistic' type of thinking as typologies are based on the assumption that observerable systematic similarities and differences exists between objects of study. The conceptual

categories along which phenomenon are classified must be separate, discrete and stable and the problem, he claims, is that they hardly ever are. He further explains that as tacit and explicit knowledge are mutually constituted – they should not be viewed as two separate types of knowledge. Tacit knowledge is the necessary component of all knowledge; it is not made up of discrete means which may be ground, lost or reconstituted – tacit and explicit knowledge are inseparably related. According to Tsoukas and Vladimirou (2001:976) organisational knowledge is the capability members of organisation have developed to draw distinctions in the process of carrying out their work, in particular in concrete contexts, by enacting sets of generalisations whose applications depend on historically evolved collective understandings. Based on this perspective Orlikowski, (2002) suggests that organisational knowledge is observer dependent and action based; it is an outcome of the process of knowing where organisational knowing refers to ongoing and situated actions of organisational members as they engage the world. Continuing with this perspective, Tsoukas and Mylonpoulos, (2004) suggest the 'constructivist' view of organisational knowledge emphasising that the content of organisational activities or the social processes/ practices surrounding the organisational activities construct and creates organisational knowledge. Supporting Leonard – Barton`s (1995) observation that a firm nurtures and creates knowledge through certain activities and these activities basically involve the sharing of knowledge within the organisation and transfer and integration of knowledge across the organisational boundaries. She further argues that firms create 'the whole system of knowledge management' through different activities and which is seen as integral element in gaining competitive advantage.

According to Tsoukas (1996) firms are distributed knowledge systems which means that they are composed of knowledge embodied individuals and their social interactions. The creation of knowledge in such system requires promotion of interaction among the individuals situated in various parts. Spender (1996b) refers to knowledge emerging from such interactions as collective knowledge. He suggest that firm's most strategically important feature is its body of collective knowledge and the key to management impact on a firm is its influence over the growth and shaping of this collective knowledge. And which is based upon the different 'organisational practises', and activities supporting those 'different practises or ways of doing things'. This view is also shared by Nonaka et al.. (2000a) as they suggest that knowledge creation is a dynamic human process; knowledge is created through the dynamic interactions among individuals and/or between individuals and their environment rather than by an individual who operates alone in a vacuum.

To summarise, the literature covering organisational knowledge creation points out that the three notable principles of knowledge include tacitness (Polayni. 1966; Nonaka and

Takeiuchi, 1995), context specificity (the extent to which knowledge is highly contextualised and co-dependent on unidentified aspects of local environment) (e.g. Nelson and Winter, 1982; Nonaka at al, 2000a) and dispersion/distribution (spread of knowledge among organisational members). The insights from various perspectives on organisational knowledge creation suggests a central role of activities or practices that facilitates interactions among distributed knowledge systems within firms for creating, sustaining or renewing organisational knowledge. Many researchers like Nonaka et al., (2000b), Cook and Brown (1999), Spender (1996b), Tsoukas (1996), Leanoard- Barton (1995) suggest organisational knowledge is located in a complex web of social practices and which have implication for capability transformation and development of new competencies.

The next section focuses on the critical process of organisational learning which facilitative the creation of new knowledge and development of capability.

4.2.2 Organisational learning

Learning is a key process by which firms accumulate knowledge in order to compete; the process through which firms create knowledge and develop technological capabilities. Dodgson (1993) defined organisational learning as the ways firms build, supplement and organise knowledge and routines around their activities and within their cultures, and adapt and develop organisational efficiency by improving the use of the broad skills of their workforces. He stresses that the importance lies in not only what a firm knows or what skills it posses, but how it uses them (Dodgson, 1993: 383). In same way Marengo (1992) argued that organisational learning is the process of generating new competencies and improving old capabilities. According to Dodgson (1993) the concept of learning provides a model for understanding the changes that individuals and organisations face.

There is increasing interest in organisational learning from different theoretical perspectives and disciplines (see for instance Hedberg, 1981; Levitt and March, 1988; Dodgson, 1993; Cohen and Levinthal, 1990; Nonaka and Takeuichi, 1995). Dodgson (1993) suggests growing interest in organisational learning is a result of increasing rate of technological change. Firms have to acquire and use the new emerging technological tools to compete efficiently. There are shorter product life cycles which necessitate learning how to do things differently. Organisations have to learn faster to become more adaptable and change themselves quickly as a response to these technological discontinuities. Firms deal with uncertainty in their markets and technologies through organisational learning which occurs through all activities of the firm. Thus learning is a dynamic and integrative concept

that can unify various levels of analysis: individual, group, and organisation and its use in theory emphasises the continually changing nature of organisations (Dodgson, 1993).

Researchers have used the metaphor of individual learning to explore processes involved in organisational learning. These researchers suggest that organisations learn through individuals as Simon (1991:76) points out that 'all learning takes place at individual level, inside individual heads; an organisation learns only in two ways :a. by the learning of its members or b. by ingesting new members who have knowledge the organisation did not have previously. In similar vein Dodgson (1993) argues that individuals are the primary learning entity in firms and it is individuals which create organisational forms that enable learning in ways which facilitate organisational transformation. However, researchers like Hedberg (1981:6) points out that although organisational learning occurs through individuals, it would be a mistake to conclude that organisational learning is nothing but the cumulative result of their members' learning. Organisations do not have brains, but they have cognitive systems and memories...organisational memories preserve certain behaviours, mental maps, norms and values over time. Therefore individual learning is an indispensable condition for organisational learning but can not be sufficient condition (Kim, 1998). Cohen and Levinthal's (1990) concept of absorptive capability can be seen as a measure of organisational learning, considering it is a set of collective abilities developed through learning activities. As they point out these activities collectively constitute what we call a firm's "absorptive capacity". Spender (1996b) points out that learning at collective level is the outcome of the interplay between conscious and automatic types of knowledge, and between individual and collective types of knowledge as they interact through collective social processes such as teamwork.

Therefore organisational learning is a social process that creates organisational knowledge through various activities involving interactions between different knowledge bases, and it is not a sum of individual knowledge bases.

Huber (1991) putting forward the behavioural perspective asserts that 'an entity learns if, through its processing of information, the range of its potential behaviours is changed'. He argued that there are four basic learning related processes that determine organisational learning. He lists those processes as knowledge acquisition, information distribution, information interpretation and organisational memory. Knowledge acquisition is the learning related process by which knowledge is obtained. Information distribution is the process by which information from different sources is shared and thereby leads to new information or understanding. Information interpretation is the process by which

distributed information is given one or more commonly understood interpretations. Organisational memory is the means by which knowledge is stored for future use (Huber, 1991: 90). This framework emphasising the focus on detailed activities within the organisations contributes to clarify the processes related to organisational learning.

Based on the observations from behavioural studies of organisations, Levitt and March (1988) point out the path dependent and cumulative nature of organisational learning. They suggest that organisations learn by encoding inferences from history into routines that guide behaviour. As Pavitt (1991:42) argues 'the range of possible choices about both product and process technologies open to the firm depends on its accumulated competence...the improvement of these competencies requires continuous and collective learning'. Therefore collective or organisational learning is dynamic, but the way it develops is constrained by existing ways of doing things, know- how and routines (Dosi, 1988); prior knowledge permits the assimilation and exploitation of new knowledge (Cohen and Levinthal, 1990).

According to Huber (1998) learning makes available the knowledge which facilitates creativity. The 'creative ideas' generated as a result of learning and knowledge in organisations are often the origin of the organisation's innovations. Cohen and Levinthal (1989) showed the dual role of R&D – as a source of innovation and as a process of learning. They argue that while R&D obliviously generates innovations, it also develops the firm's ability to identify, assimilate and exploit knowledge from the environment ...a firm's "learning" or absorptive capacity and these two roles of the R&D contribute to the firm's competitiveness (Cohen and Levinthal, 1989: 569). They argue that organisational learning is a function of an organisation's absorptive capacity and it is internal mechanisms within the firm that influence its absorptive capacity or ability to learn.

To summarise review of organisational learning literature shows that learning is viewed as a complex , history dependent and target oriented process and suggests an empirical focus on the detailed activities within organisations as a way to understanding complexities involved in organisational learning.

The next section focuses on innovation management and identifies various processes involved in application of diverse knowledge bases in creating innovations.

4.2.3 Product innovation management: Integration and coordination of different knowledge bases

The research on innovation management explains some factors that facilitate the learning and knowledge creation. The innovation management literature deals with knowledge

creation, by focusing on the product innovations, and offers some explanation for management practises that facilitate the achievement of innovations. Coombs and Hull (1998) suggests that the perspectives in innovation management literature links knowledge to innovation by focusing on firm specific routines and processes, which 'stabilises certain bodies of knowledge, embed them in shared understanding in the firm, and provide templates for deploying that knowledge to produce innovations which have distinctive organisational signature'.

The different types of knowledge and their role in innovation have also dominated the innovation management literature. For example, in the case of the development of a particular product, an individual might initiate an idea. But in order for this idea to become a product innovation that generates value for the firm, it has to be combined with other types of knowledge, such as research & development, manufacturing, marketing and customer service while at the R&D project team level it involves different specialised disciplinary knowledge bases. This simple description of innovation creation process shows involvement of various types of knowledge. A variety of studies have developed categorisation of knowledge used in innovation, which go beyond a simple distinction of tacit and explicit knowledge. Faulkner, (1994) presents a 'composite typology' of 15 categories of knowledge used in industrial innovation. Therefore the complexity of the task, such as 'product innovation fulfilling demands of external markets', requires diverse knowledge sets (Leonard – Barton, 1995; Nonaka – Takeuichi, 1995) and in such cases successful management of knowledge for innovation requires the organisational capacity to orchestrate and integrate functional and specialist groups (Pavitt, 2002).

Although it is well understood that firms integrate knowledge all the time at different levels, they do it even without calling this activity as integration, without any clear objective of doing it and without setting specific mechanisms to facilitate the process. However as Tidd et al., (1997) observed, 'internal structures and processes must continuously balance potentially conflicting requirements:

1. to identify and develop specialised knowledge within technological fields, business-functions and product divisions,
2. to exploit this knowledge through integration across technological fields, business functions and product divisions'.

The process of knowledge specialisation and the need to integrate knowledge across organisational boundaries refer to different aspects of the firm's activities. Due to this conflict Pavitt (2003) suggests that it is necessary for firms to strategically manage integration of different specialised knowledge across the organisational boundaries of the firm. The investment in organisational level integrative management practices facilitate

interactions to create knowledge among individuals situated in different parts of a system independently (Un and Cuervo- Cazurra, 2004).

In strategic management literature, integration is analysed in the context of problem solving activities, which are considered to be basic units of knowledge creation. Henderson and Cockburn (1994) point out that the externally focused integration: ability of firm to access knowledge from outside boundaries of organisation and internally focused integration, that is, ability to integrate flexibly across disciplinary and therapeutic class boundaries within organisation is very important. External integration refers to problem solving activities that span the boundary between the firm and its external environment. It is related to generations of options using external sources of information and to the ability to evaluate those options according to existing knowledge base (Iansiti and Clark, 1994:565).

The other important aspect of managing knowledge for innovation is the coordination of learning activities as these mechanisms plays a central role in shaping organisational learning process and determining its outcome (Marengo, 1992). In complex organisations many different learning processes can proceed at the same time in different directions and at different speeds (Dodgson, 1993). Managers have different perceptions about the world and understanding about innovation activity and organisational units have to play different roles in overall innovation activity of the organisation. For these and other reasons the organisational units follow different paths of learning and build different knowledge bases. Hence coordination of learning within different units is required to be able to integrate knowledge and build strategic capabilities.

To sum up, the product innovation management literature shows that the integration of different specialised knowledge bases and coordination of learning are crucial processes in building knowledge creation capabilities for innovation

The literature based on organisational knowledge creation, learning and innovation points out the broader aspect of activities involved in managing knowledge, learning and creating innovation.

A. Researchers from different theoretical perspectives have emphasised that organisational knowledge or capabilities or learning is not the sum of individual level knowledge, capability or learning. This is quite evident in concepts such as collective knowledge (Spender, 1996a), absorptive capacity (Cohen and Levinthal, 1990), architectural knowledge (Henderson and Clark, 1990) which are highly firm specific capabilities fed

by the learning processes or capabilities or knowledge bases of individual members but can not be reduced to their sum. In particular, activities and processes facilitating the relations and interactions among different parts of the organisation play a fundamental role in driving and shaping the organisational knowledge (Tsoukas, 1996, Spender, 1996a).

B. The brief review of product innovation management literature suggests that organisational level integrative practices reinforce each other and promote knowledge creation by establishing interactions and interdependencies among individuals with different knowledge sets (Un and Cuervo – Cazurra, 2004). Therefore in firms from advanced countries it emerges that success in innovation management depends on the effective integration of specialists (discipline, function, division) within the firm and on effective outside linkages with sources of expertise, and with needs of eventual customers (Bell and Pavitt, 1993).

These insights provide the outline of the theoretical framework while the large pharmaceutical firms' approaches to advances in molecular biology help in operationalising the theoretical framework which is discussed in the next section.

The molecular biology advances had a profound impact on drug discovery and development technology. These advances emerged from academia and research institutes and shifted the scientific knowledge base of the industry, more precisely it shifted drug discovery process from one being chemistry dominated to being molecular biology dominated. This created discontinuous innovation for large pharmaceutical firms which had little control over these technological developments. As a result the large pharmaceutical firms' were forced to develop new competencies in biotechnology. This represents a good example of discontinuous learning or dynamic learning as a response to technological change and aids in operationalising the framework. In the case of Indian pharmaceutical firms the challenge of innovative R&D similarly represents the challenge of different knowledge base. Therefore knowledge processes involved in the large pharmaceutical firms discontinuous learning emerges as an effective guide in exploring Indian pharmaceutical firms approaches.

4.3 Large pharmaceutical firms and the 'biotechnological' change

The last 25 years have seen a revolution in the life sciences that has had several dramatic effects on the global pharmaceutical industry. Biotechnology and its impact provide an intriguing window into how the basic scientific advances affect the established

competencies of the firm and how firms can adopt and change in the face of such challenges.

The advances in molecular biology and related technologies originated from academic research in biological sciences, and its practitioners designed drugs based on scientific hypotheses. The drug discovery technology dominant in the 1970s and into the 1980s, in pre- biotechnology era, was based on the chemistry and heavily involved the use of medicinal chemistry and pharmacology to discover effective molecules. This was reflected in large pharmaceutical firms building up comprehensive research strengths in chemistry rather than biology. Therefore emergence of advances in genetic and genetic engineering popularly known as biotechnology profoundly affected the scientific and technological basis of pharmaceutical industry (Galimberti, 1993; Sharp, 1995) and represented a dramatic shift in the '*scientific*' knowledge base of an industry (Zucker and Darby, 1997; Henderson et al., 1999). Zucker and Darby (1997) refer to these advances as 'archetypical example of externally generated, incumbent skill obsoleting, discontinuous innovation' which the literature predicts leads to the replacement of incumbents (pharmaceutical firms) by entrants (new biotechnology firms). However despite the sweeping natures of molecular revolution, incumbent pharmaceutical firms have not been swept away by new entrants but on the contrary a substantial number of incumbent firms have flourished at the same time. Incumbent firms successfully responded to technological challenge by transforming existing capabilities and developing new competencies.

Zuber and Darby (1996a) report extensive transformation of most of the world's top twenty drug discovery firms by the early 1990s as evidenced by discovery of new biological entities, genetic sequence patents and co publishing with top academic biotech scientists. They suggest that drug discovery pharmaceutical industry appears to present the case in which numerous firms have pursued a strategy of transformation of technological identity – adopting the new technological trajectory rather than pursuing the 'underinvestment and incompetence as responses to radical innovation. According to Henderson et al., (1999) the case of the molecular biology revolution and the response from firms provides the detailed mechanisms of industrial transformation at the firm and industry levels, with the co-evolution of scientific knowledge on one side and organisational capabilities, industry structure and institutional context on the other side.

The next section presents the overview of biotechnology challenge and follows it with mechanisms used by large pharmaceutical firms to change their technological identity and capabilities.

4.3.1 Overview of Biotechnology change

The revolution in genetics and molecular biology that began more than 40 years ago with Watson and Crick's discovery of the double helix structure of deoxyribonucleic acid (DNA) and that continued with Cohen and Boyer's discovery of the techniques of genetic engineering. This discovery had an enormous impact on the nature of pharmaceutical research and development and on the organisational capabilities required to introduce new drugs (Henderson et al., 1999: 283). Initially application of these advances followed two relatively distinct technical trajectories. One trajectory was rooted in the use of genetic engineering as process technology to manufacture proteins while second trajectory was concerned with using advances in genetics and molecular biology as tools to enhance the productivity of the discovery of conventional 'small molecule' synthetic chemical drugs. In recent years these two trajectories have converged and now efforts in biotechnology are largely focused on the search for large molecular weight drugs like proteins that must be produced using tools of genetic engineering but whose therapeutic value, as yet, not fully understood.

4.3.1a Biotechnology as a process technology

Traditionally, most drugs have been derived from natural sources or synthesised through organic chemical methods. These traditional methods were not suitable for the production of molecules with a large molecular weight like proteins. Proteins are simply too large and complex to synthesize feasibly through traditional synthetic chemical methods. In this regard Cohen and Boyer's key contribution was the invention of a method for manipulating the genetic characteristics of a cell so that it could induce to produce a specific protein. This invention made it possible for the first time to produce a wide range of proteins synthetically and thus opened up entirely new domain of search for new drugs. So, for firms choosing to exploit this route the key organisational capabilities have been those of manufacturing and process development: learning to use the new rDNA techniques as a process to produce natural or modified human proteins. The development of this competence created significant challenges for nearly all of the established pharmaceutical firms since it required both the creation of an enormous body of new knowledge and a fundamental shift in the ways in which manufacturing process development was managed inside the firm. The characteristics of knowledge base underlying successful biotechnology process development are quite different. Therefore an organisation developing a process for protein molecule needs not only new technological or scientific capabilities, but also different organisational capabilities than those required

for the development of a manufacturing process for a new small molecular weight compound.

4.3.1b Biotechnology as a research tool

The new techniques of genetic engineering through their impact on the competencies required to discover 'conventional' small molecular weights affected the organisational competencies required to be a successful player in the pharmaceutical industry. The tools of genetic engineering initially employed as a source of screens with which to search for new drugs. In later years, new strategies emerged regarding usage of biotechnology, in first the therapeutic properties of a known protein were explored for curing disease state while in second strategy the focus was on the specific disease or condition and to attempt to find a protein that might have the therapeutic effects. More recently the pursuit of biotechnology has come to require new competencies in drug research because it has fundamentally shifted both the domain and the methods of search for new therapeutic agents. In the traditional synthetic chemical world researchers' searches among the entire universe of small molecules, however biotechnology researchers search focuses on more than 500,000 proteins present in the human body. This search requires quite different technical and organisational capabilities since it calls for firms to develop a deep understanding of the role of particular proteins in causing disease. Firms choosing to use biotechnology- based research tools thus had to strengthen their scientific capabilities especially in biological sciences.

This way the techniques of molecular biology had dramatic implications both of the discovery of new drugs, on one hand and for the ways in which they were manufactured on other hand. An extensive literature has documented some of the consequences that the advent of molecular biology has produced on the organisation of innovative activities both at the firm and industry level (Orsenigo et al., 1998; Henderson et al., 1999; Gamberdella, 1995; Galambos et al., 1998) and it is briefly discussed in next section.

4.3.2 Transformation of the identity at large pharmaceutical firms

Managing the transition into the biotechnology era was not straightforward matter and the following section covers activities involved in transformation of technological identity by large pharmaceutical firms. The large pharmaceutical firms responded to technological advances by acquiring the component knowledge bases and reconfiguring the linkages between them.

4.3.2a Acquisition of new knowledge and internal transformation

The revolution in life sciences changed the organisational and managerial aspects of the drug research; drug research became more knowledge intensive and complex. As a result it brought changes in the internal structure of commercial R&D; drug companies began to look and behave more like universities with increasing emphasis on collaborations, publication and willingness to exploit external sources of technology (Cockburn, 2004).

According to Henderson (1994) in pre biotechnology era, drug discovery drew on three disciplines: analytical chemistry, basic pharmacology and ability to screen thousand of compounds through multiple screens. Many firms were organised functionally, with medicinal chemists at heart of the process and pharmacologist working down stream in a fundamentally reactive mode. This method of drug discovery required little communication of knowledge either across the boundaries of the firm or across disciplines of or therapeutic areas within the firm. But due to advances in molecular biology, this functional organisation of R&D became redundant. In post biotechnology era, modern drug discovery requires the input of scientists skilled in wide range of disciplines and as a consequence large research oriented pharmaceutical firm now employ molecular biologists, physiologists, and biochemists as well as specialists in the traditional disciplines of synthetic chemistry and pharmacology. This change in the dominant mode of drug discovery greatly increased the need for the exchange of knowledge across the boundaries of the firm and across disciplinary and therapeutic class boundaries within the firm. Thus the ability to take advantage of biotechnological techniques in drug research required a very substantial extension of the range of scientific skills employed by the firm; a scientific work force that was tightly connected the larger scientific community and an organisational structure that supported a rich and rapid exchange of scientific knowledge across the firm (Henderson at al., 1999).

Zucker and Darby (1996b) indicate that the large pharmaceutical firms focused on the internal R&D transformation primarily by hiring new personnel embodying the new technology and incorporating them into the existing structure. In post biotech era the 'star scientists' combining genius and knowledge of emergent technologies became the gold deposits around which firms and their success was built. Henderson, (1994) suggests that the extent of the adoption of new techniques also involved the successful adoption of particular, academic like, forms of organisation of research within company. According to Galambos et al., (1998) large pharmaceutical firms adopted two approaches for acquiring biotechnology capabilities. The more common strategy was to start by developing specialised expertise in biotech application and then attempting to generalise it across a

range of different therapeutic categories. It involved the building biotechnology capability through the process of internal group building. This represented the incremental approach and involved increasing investment in in-house biotech R&D to develop competences in new techniques.

The second strategic alternative pursued by large pharmaceutical firms involved acquisition of biotech capabilities by establishing licensing, research and equity relationships with biotech enterprises. Cockburn (2004) pointed out that internal transformation was accompanied by increased willingness to exploit external sources of knowledge through in-licensing or strategic partnerships. Supporting this observation Nicholls- Nixon (1993) shows that large pharmaceutical firms developed new capabilities by investing in biotechnology related R&D activities and accessing new external technological linkages. The in-house scientific research raises the ability of firms to take advantage of public sciences (Cohen and Levinthal, 1989; Gamberdella, 1992). Therefore internal R&D is an important pre-requisite to use strategic alliances as means of acquiring knowledge. In the case of large pharmaceutical firms, these strategic alliances, collaborations transformed organisation of R&D and played a critical role in development of biotechnology competence.

4.3.2b Mechanisms of knowledge transfer and inter firm networks:

Most of the major firms invested in biotechnology R&D through collaborative R&D arrangements, R&D contracts and joint ventures with new biotechnology start ups (Arora and Gamberdella, 1990; Pisano, 1990). The collaborations and joint ventures with university scientists and new biotechnology firm were primarily used to augment internal expertise (Zucker and Darby, 1997). In general major incumbent firms began to acquire the technology through processes of collaboration – both with small biotechnology firms and directly with university laboratories – and then moved gradually through a process of outright acquisitions of small firms. Zucker and Darby (1997) found that research collaborations between firm scientists and university or research institutes scientists working in biotechnology area had positive effect on firms' effort to develop biotechnology capabilities. Cockburn et al., (2000) suggest that the rate at which large pharmaceutical firms adapted to biotechnology was largely determined by the degree to which they were active participants in public science.

Supporting this observation, Gamberdella (1995) explained that large pharmaceuticals used different forms of linkages with universities, research institutes as mechanisms of knowledge transfer to complement internal capabilities in biotechnology. He identified

four types of linkages like research and /or joint development agreements with other firms, research agreements with universities, investments in the capital stock of biotechnology firms and acquisitions of biotech firms. Focusing on the biotechnology industry he reason that agreements signed by large pharmaceutical firms with new biotechnology firms (NBF) tend to be product specific and aimed at developing and commercialising discoveries made by new biotechnology firms. Alternatively agreements with universities usually focused more on basic research and are undertaken as a means of obtaining basic knowledge in a field and securing the first option to license discoveries resulting from research. Minority equity positions in new biotechnology firms are used to monitor the internal research activities of the NBF and to establish preferential links. Finally acquisitions are initiated for two reasons: either to complement the large firm's internal capabilities in specialised areas of technology, or to supplement the firms existing capabilities; as means of catching up. Powell (1998) elaborates on the extensive efforts taken by biotechnology and pharmaceutical firms in developing capability to collaborate and learn.

These observations suggests that with the emergence of biotechnology established incumbent firms in the pharmaceutical industry were forced to form new relationships with universities and new biotechnology firms in order to access the knowledge needed to build their own capabilities in biotechnology. Thus in order to remain competitive in biotechnology era, incumbent firms extensively used external relationships as a vehicle for adjusting their internal technological capabilities.

This provides the additional evidence of the use of network strategies by large pharmaceutical firms and new biotechnology firms. These changes led to transformation of new drug discovery and development in large pharmaceutical firms from a totally in-house activity to a networked collaborative activity. Therefore in recent years, a dense network of collaborative relationships among different types of firms and other research institutions has emerged as a major feature of the transformation of large pharmaceutical firms' technological capabilities as a response to biotechnological change.

To sum up, the case of biotechnology or advances in biological science made several of the core competencies of existing pharmaceutical firms' obsolete (Henderson et al., 1999). As a response to these challenges, large global pharmaceutical firms acquired biotech capability by hiring the star scientist, restructuring internal mechanisms of managing research, accessing in new external sources of knowledge and investing in the internal biotech R&D. These firms collaborated, and in some cases acquired the new biotech firms and changed the in-house nature of their R&D to the network model of the R&D. As Zucker and Darby (1997) suggests the transformation of technological identity as a

response to radical innovation by large pharmaceutical firms provide us better understanding of mechanisms used by incumbent firms to transform in face of an external technological discontinuity. In case of Indian pharmaceutical firms these mechanisms helps in focusing on the areas of investigation.

The next section presents the detailed theoretical framework which is based on the insights from review of literature on knowledge based theory of the firm, organisational learning and product innovation management along with mechanisms used by large pharmaceutical firms to transform its capabilities and identity.

4.4 Theoretical Framework for analysing the firm level processes involved in development of competency for innovation

This chapter has reviewed literature about the role of the different processes involved in mechanisms of managing knowledge, learning and innovation and its role in development of capabilities for firms in changing environments. The experience of today's developed and developing countries shows that the differentiated and path dependent processes of learning are the basis for changing capabilities as they develop and so both historical and contemporary analysis needs to be undertaken in order to understand the dynamics of these processes fully (Nelson and Winter, 1982; Bell and Pavitt, 1993). Therefore the theoretical framework focuses on both historical and contemporary analysis of processes involved in learning and change in Indian pharmaceutical firm.

In the case of some events, such as fundamental regulatory reforms or radical technological advances, firms have to go through revolutionary change or discontinuous learning to develop new competencies to adapt and change. This ability of the firm to learn, change and develop new competencies is termed by Teece et al., (1997) as dynamic capability. According to Teece and Pisano (1994) dynamic capability of the firm refers to the capacity of firm to renew competencies so as to achieve congruence with changing business environments. It refers to firm's ability to make effective use of knowledge in efforts to assimilate, use, adapt and change existing technologies. Therefore it enables firms to create new technologies and to develop new products and processes in response to changing economic environment.

Discontinuous learning normally involves a crisis and a strategy to turn the situation around whereas cumulative or incremental learning is learning that can take place along current trajectory under normal circumstances (Tushman and O'reilly, 1996; Kim, 1998). The example of large pharmaceutical firms' development of biotechnology capability as response to advances in molecular biology represents one such example of discontinuous learning. In catching up countries, particularly where the state plays an orchestral role in

industrialisation, the change in government policy or new regulation could impose a crisis in particular industry. This creates greater challenge for firms in developing countries to become more adoptable and respond to change more quickly requiring rapid and greater learning. The review of strategic management literature suggests that the capability of the firm to renew or reconfigure technological capabilities is based on the ability of the firm to develop new competencies by acquiring new knowledge and integrating or combining it with existing knowledge bases (Kogut and Zander, 1992, Teece, et al., 1997; Cohen and Levinthal, 1990; Pavitt, 2002). In similar vein Henderson and Clark, (1990) show that in order to adapt and change as a response to such challenges, firms must learn not only new components of knowledge but also the new linkages between the components and so requires the reconfiguration of existing system of managing and creating knowledge in new way. In the case of pharmaceutical R&D, the biotechnological change - more specifically the pursuit of large molecular weight compounds such as drugs - required new competencies in both research and process development, and subsequently it altered the relationship between different components of knowledge involved in pharmaceutical R&D. Therefore as different researchers have shown as a response to biotechnological change large pharmaceutical firms not only developed new competencies through discontinuous learning but also reconfigured existing system of managing and creating knowledge in new way.

The firm's ability to develop new competencies depends upon its learning capacity, that is, on its ability to acquire, create and disseminate new knowledge. Cohen and Levinthal (1990) refer to this organisational capacity to generate new knowledge as absorptive capacity and define it as an ability of firm to identify, assimilate and apply external knowledge. However they suggest that absorptive capacity tends to be cumulative and path dependent as it builds on prior knowledge base and experience which is firm specific. The prior knowledge base is an essential component in firm's learning ability or absorptive capacity as existing knowledge increases ability to make sense of, assimilate and apply new knowledge. Firms tend to move along particular trajectories in which past learning (by doing and by other mechanisms) contributes to particular directions of technical change, and in which the experience derived from those paths of change reinforces the existing stock of knowledge and expertise (Bell and Pavitt, 1993). The stock of past capabilities, routines provides the base on which firms develop the capabilities to cope with new technological change or new external environment: change is certainly possible, but it is conditioned by past. Patel and Pavitt (1994, 2000) showed that firms are in fact heavily constrained by their prior competencies in the extent to which they are capable of accumulating competencies in new emerging fields.

The transformation of drug discovery and development in large pharmaceutical firms from totally in-house activity to a networked collaborative activity suggests that firms need to use external relationships to access relevant knowledge outside the boundaries of the firm. as support to efforts in internal capability development but not as substitute to internal investment. Technical change is generated out of complex interactions between firms. These interactions involve a wide range of technology collaborations arrangements between competing as well as complementary firms, while others involves linkages with public sector research activities. Thus an important part of the process of accumulating industrial technological capabilities involves various kinds of institutional structures within which firms can interact in creating and improving the technology they use. However just establishing the collaborative arrangements for interactions is not enough to facilitate the transfer of knowledge. Bell and Pavitt (1993) focusing on knowledge transfer, suggest that the transfer of technological knowledge cannot be wholly embodied in equipment or instructions, patents, designs or blueprints. Transfer necessarily requires learning because technologies are tacit and their underlying principles are not always understood and therefore successful knowledge transfer requires careful management of communication between involved entities.

Absorptive capacity also refers to the organisation's ability to exploit externally acquired or assimilated knowledge. Therefore an organisation's absorptive capacity does not simply depend on the organisation's direct interface with the external environment but it also depends on the transfers of knowledge across and within subunits that may be quite removed from original point of entry. The structure of communication between the external environment and organisation as well as among sub units of the organisation is an important determinant of absorptive capacity (Cohen and Levinthal, 1990:132).

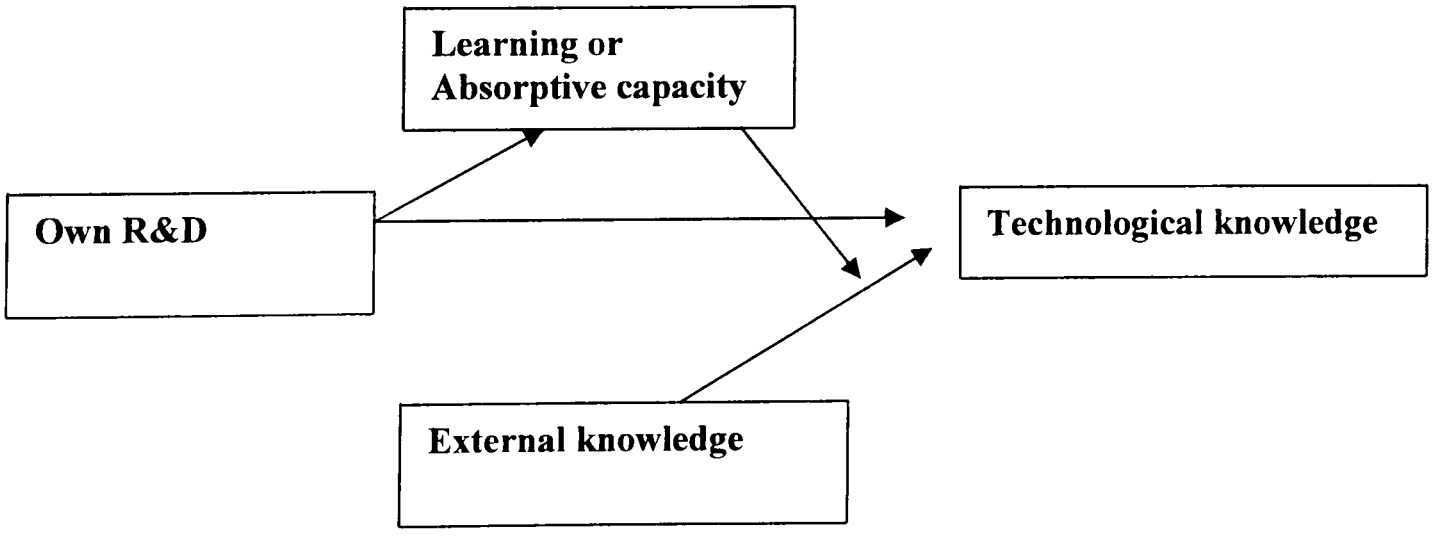


Fig.4.4 Model of sources of firm's technological knowledge (Source: Cohen and Levinthal, 1990)

Thus an organisation's absorptive capacity or capability to learn depends on: prior knowledge base, that is, the sum of the abilities of all the individuals in organisation to recognise what they know and the way(s) in which they know; and mechanisms of knowledge transfer; the effectiveness with which information or knowledge is transferred externally between firm and external source as well as internally from one unit to another (Fig. 4.4). Zahra and Gorge (2002) re-conceptualised absorptive capacity as a dynamic capability and distinguish it in two sub sets of potential and realised absorptive capacities. Potential capabilities comprises of knowledge acquisition and assimilation while realised capabilities centres on knowledge transformation and exploitation.

Absorptive capacity is thus a function of two separate but interrelated dimensions: a. the firm's ability to acquire the knowledge relevant to the new technological paradigm, and b. firm's ability to integrate external knowledge into existing capabilities.

The theoretical framework broadly focuses on practices or mechanisms associated with these two dimensions of absorptive capacity. So its focus is on the transformation of what happens in 'practise' as a response to change in external environment. It covers accumulation mechanisms which govern the content and location of stocks of knowledge in the firm; the transfer mechanisms which govern the balance between, internal and external sources of knowledge; it includes assimilation mechanisms which governs the way in which firms internalises the newly accessed knowledge and is also focuses on application or deployment mechanisms like coordination and integration practises which govern the ways in which the stocks of knowledge or specialised knowledge bases are brought to bear within decision making.

The review of relevant literature suggests that these mechanisms play an important role in creating, constructing and defining collective knowledge in organisations (Tsoukas, 2000).

The other approaches or frameworks focusing on the firm level studies in developing countries mostly concentrated on the differences in tacit and explicit knowledge or between individual, group and organisational knowledge and conversion of different knowledge types knowledge to create organisational knowledge (see for instance Kim, 1997a; Dutŕenit, 2000). However varieties of innovation studies have shown limitation of such approach as categorisation of knowledge for innovation reflects a fair degree of overlap. The knowledge used in innovation does not come in watertight boxes but is mutable and multidimensional, precisely because of complex social processes by which it is generated and utilised (Faulkner, 1994). The review of organisational knowledge creation literature also suggests that the social processes that facilitate interactions among distributed knowledge systems within as well as across firms enable the creation of knowledge and in this research those social processes are explored. Therefore the focus of

theoretical framework is practices or processes involved in managing and creating knowledge in contrast to other approaches used for exploring firm based learning processes in developing countries.

Therefore based on insights from discussion, the theoretical framework (Fig 4.5) focuses on the social processes or mechanisms used for knowledge acquisition, transfer. assimilation, and application. It also explores the relevance of prior knowledge base in terms of its usefulness in new environment and how firms have built it. The areas of investigation are,

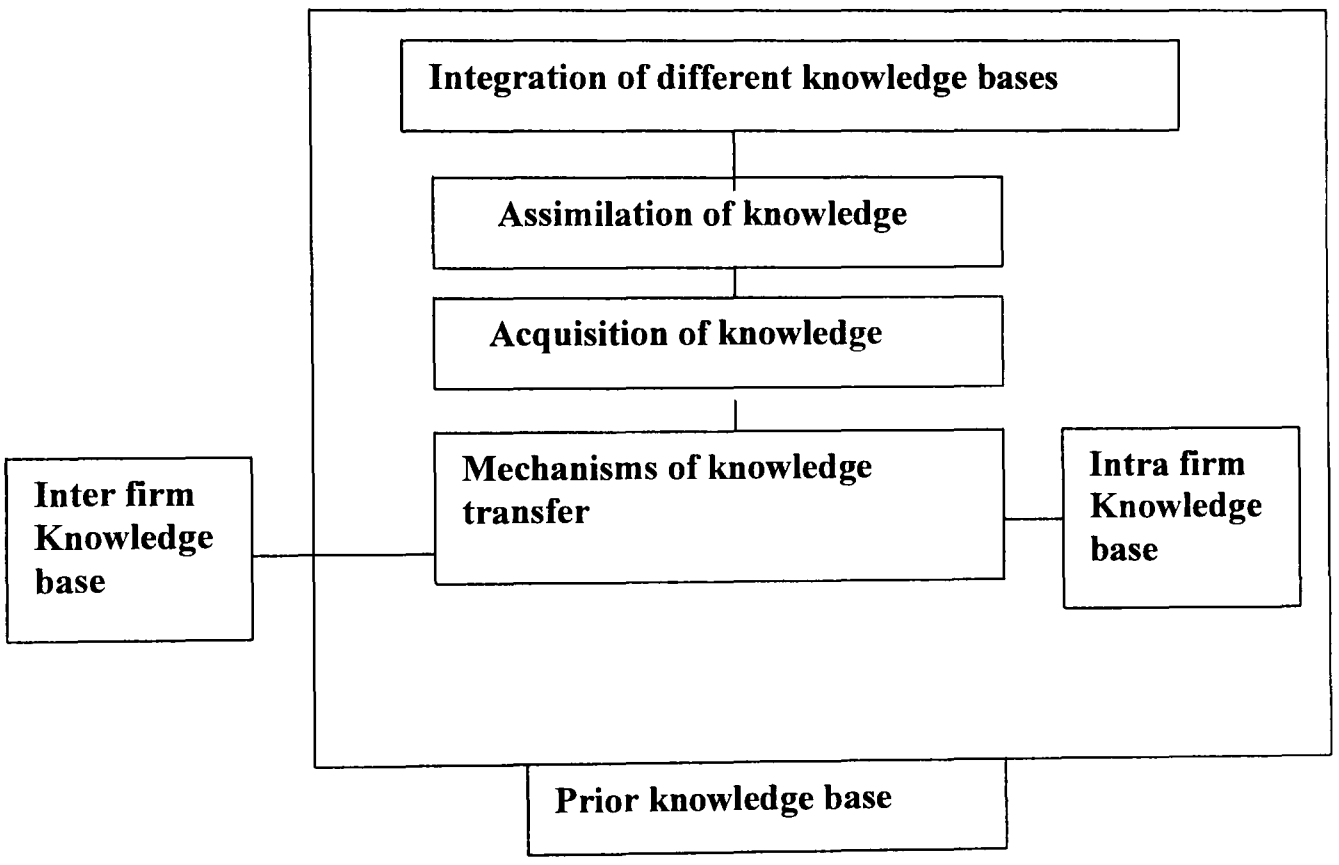


Fig.4.5 Theoretical Framework

4.4.1 Prior knowledge base

In the case of the Indian pharmaceutical industry this research explores the nature of the existing knowledge base, how Indian firms developed that knowledge base and its relevance in innovative R&D.

In case of large pharmaceutical firms' response to technological change, organisations which had indulged in fundamental science under the random screening period regime or pre-biotechnology era were at a considerable advantage in adopting the new techniques. This investment in fundamental research helped these firms in creating prior knowledge base and establishing links with the outside sources of knowledge like academia and research institutes which were the originators of the new technology (Gamberdella, 1995;

Zucker and Darby, 1997). This observation supports the Cohen and Levinthal`s stress on prior knowledge base and its role in learning.

4.4.2 Acquisition of knowledge

Knowledge acquisition is a learning related process by which knowledge is identified, accessed and obtained. The large pharmaceutical firms' approaches to biotechnological change show that investment in internal R&D played crucial role in transformation of technological identity. It not only generated new knowledge but also created firm`s ability to exploit external knowledge (Nichols- Nixon, 1993). Other mechanisms adapted by large pharmaceutical firms include learning by hiring, acquisitions of new biotechnological firms, training and collaborative R&D.

So in the case of Indian pharmaceutical firms this research explores how firms are acquiring knowledge to develop competency in innovative R&D.

4.4.3 Mechanisms of Knowledge transfer: Inter firm and intra firm linkages

The mechanisms of knowledge transfer here refer to the mechanisms of communication between the external environment and the organisation but also among subunits of the organisation as the organisation's absorptive capacity does not simply depend on its direct interface with the external environment but it also depends on transfer of knowledge across and within subunits. Knowledge transfer here is based on Appleyard's (1996) definition of knowledge transfer; 'transfer of useful know-how and information across and within firm boundaries'.

External linkages or alliances enable large pharmaceutical firms to develop basic knowledge in a number of technological areas, (Arora and Gamberdella, 1990). Cockburn and Henderson (1998) suggest that in the pharmaceutical industry it is important for firms to be actively connected to the wider scientific community. As a result of biotechnological change, large pharmaceutical firms' transformed the integrated in-house nature of pharmaceutical R&D to a networked model of collaborative R&D.

So in case of the Indian pharmaceutical firms this research explores the inter-firm relationships and mechanisms of knowledge transfer involved in development of competence for innovative R&D.

4.4.4 Mechanisms involved in knowledge assimilation

The assimilation of knowledge involves the creation of an environment which facilitates the process of sharing experiences as without a shared language and a shared way of discussing, it is difficult to create uniform purpose, construct cohesive meaning, and learn in ways which support innovation across the organisation. Organisational routines are one way in which knowledge generated by individuals becomes assimilated or embedded in organisations. Hedberg (1981:3) suggests that organisations have cognitive systems and memories; members come and go and leadership changes, but organisations' memories preserve certain behaviours, mental maps, norms and values over time and this represents the assimilation of knowledge.

So only bringing in some knowledge (by hiring individuals or making acquisitions) is not enough; it must be also assimilated and made useful. Therefore in the case of learning by hiring; brining in key individuals is not enough but it is also important to analyse where, when and how the knowledge possessed by these hired individuals is socialised at the organisational level.

In the case of large pharmaceutical firms' response to technological change, Henderson, (1994) suggests that the extent of the adoption of new techniques in incumbent firms involved the successful adoption of a particular, academic like, form of research organisation. This led to building an environment which encouraged sharing or transferring of knowledge within firm.

Therefore in the case of Indian pharmaceutical firms, this research explores how firms built an environment in which individuals create and share knowledge and facilitate development organisational competency in innovative R&D.

4.4.5 Mechanisms involved in knowledge application - Integration of different knowledge bases

According to Cohen and Levinthal (1990: 134) complimentary functions within the organisations ought to be tightly intermeshed to create cross functional absorptive capacities and superior innovative performance. Some of the integrative mechanisms mentioned in the innovation management literature includes teamwork based on cross functional and cross disciplinary teams (Iansiti and Clark, 1994; Henderson and Cockburn, 1994), overlapping problem solving, redundancy of knowledge or shared knowledge and expertise, strategic rotation of personnel (Nonaka and Takeuichi, 1995), boundary spanning or integrators: individuals who stand at the interface between different specialised units, knowledge bases or internal and external knowledge (Allen, 1977); project focused organisational structure and processes (Henderson, 1994); small teams

with broad task assignments and a 'heavy-weight' product manager (Clark and Fujimoto,1990). In case of pharmaceuticals Henderson (1994) suggest that successful pharmaceutical firms maintained high level of information flow across the boundaries of scientific disciplines and therapeutic areas within firm by organising research by therapeutic area or by using cross disciplinary teams, by making world wide research through single organisation and by allocating resources through committee rather than using single individuals to make key decisions.

In the case of the Indian pharmaceutical industry, this research explores how firms are integrating different disciplinary knowledge to develop competence in innovative R&D.

4.5 Conclusion

This chapter presented the theoretical framework used for exploring the firm level process involved in redevelopment of knowledge creation capability for innovation in Indian pharmaceutical firms as a response to change in external environment. The concepts from organisational knowledge, learning and innovation management literature provide an outline for the theoretical framework. Large pharmaceutical firms' response to technological change directs the focus of the theoretical framework, which is the 'organisational processes or activities involved in creation or construction of knowledge' for innovation.

Chapter 5

RESEARCH METHODOLOGY

5.1 Introduction

This chapter presents the research methodology adopted in this research. It discusses the various methodological issues concerned with research design like different stages associated with research process, rationale behind the selected research strategy, sources of managerial and technical data and techniques employed for analysing the data.

This research explores the effect of change in patent law on strategic orientation and learning processes in the Indian pharmaceutical industry. However, the main focus of this research is studying the processes involved in the transformation of existing capabilities and development of new technological competencies for innovation as a response to strengthening of patent law in Indian pharmaceutical firms. Thus this research covers these two issues and as a result designing a piece of research within this challenging field became very problematic.

Chapter two discussed various issues concerned with IPR laws and provides background to the whole study. It basically focused on the genesis of the research which is 'implications of strengthening of patent laws for pharmaceutical firms in developing countries'. This chapter shows the various approaches and issues employed by different researchers to study the impact of change in patent law. This discussion clearly indicates the complexity involved in researching impact of changes in patent law on pharmaceutical firms and their strategic responses to such change. Therefore progressive or phased based research methodology was adopted, with each piece building on the findings of the earlier phase.

The first phase of this research focused on understanding the implications of change in patent law for the Indian pharmaceutical industry and strategic responses of Indian firms to this change while the second phase investigated learning processes adopted by these firms to develop strategic knowledge creation capability for innovation.

The first phase helped in improving knowledge about the real impact of change in patent law on the Indian pharmaceutical industry, different strategic approaches adopted by Indian firms and rationale of Indian pharmaceutical firms for selecting innovative R&D as one of the important source of survival and growth in strong patent era.

The findings from the first phase suggested some of the firms in the Indian pharmaceutical industry are responding to changes in patent law by developing competencies for

innovative R&D. The innovative R&D in the pharmaceutical industry is represented by new chemical entity or new drug delivery research and which is quite complex in nature. making the whole process highly risky and costly. Considering the resources available to Indian pharmaceutical firms, the movement of Indian firms towards development of competencies in innovative R&D raises some important questions.

It may be useful at this point to reiterate the main research objectives which were presented in chapter one and two as research questions:

- **How are Indian pharmaceutical firms building strategic knowledge creation capability for innovation as a response to change in regulations?**
- **How relevant is knowledge accumulated through imitation for firms in their efforts to create innovative novel products?**

Chapter three reviewed the literature focused on capability development and showed the inadequate treatment given to "transformation or renewal of capabilities in firms from developing countries" in the developing countries literature as well as in strategic management literature. The transformation of capabilities by Indian pharmaceutical firms provided the ideal opportunity to study "dynamic learning processes involved in development of new competencies for innovation in firms from developing countries".

A qualitative multi method approach was chosen as the best way to arrive at an encompassing process view of transformation of capabilities and development of new competencies. The theoretical framework developed in chapter four helped in clarifying the area under investigation. It also guided the development of priori constructs and directed the collection of data.

The next section explains in detail the 'progressive or phase-based methodology and issues concerned with its implementation.

5.2 Research process, design and methodology strategy

Generally the genesis of research in disciplines like social sciences lies in 'new event' or 'dilemma' which can not fully be explained or comprehended by present or existing knowledge. In management science, it gives rise to the management question, which is then framed as a research question. The Research Process model (Fig.5.1) shows different steps in the research process that need careful consideration from the point, when (new) events or dilemmas' are identified and converted into "problems", when research questions

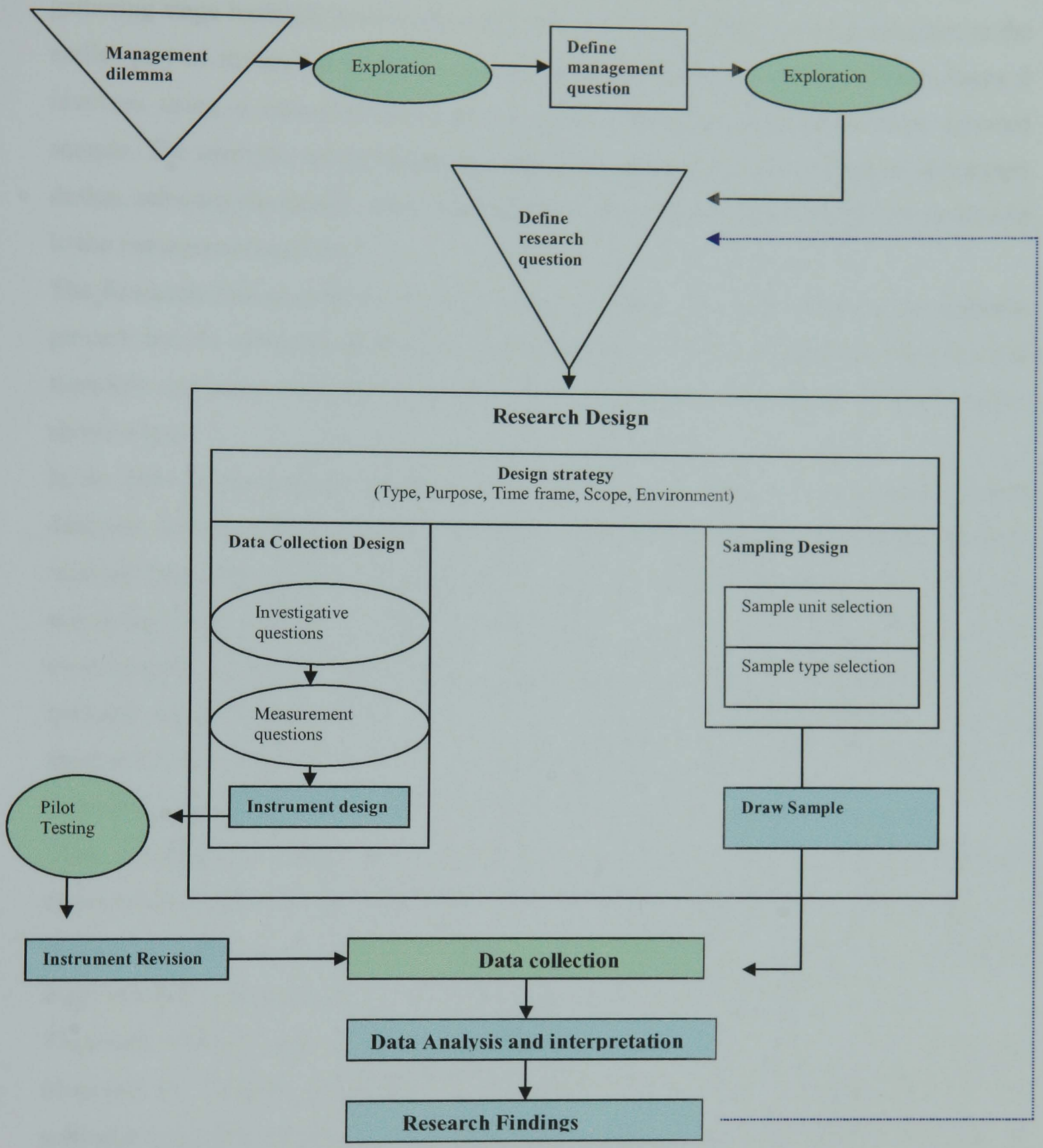


Fig. 5.1 Research Process (Source: Author's modification of original model from BID (2002))

are posed and when research strategies are chosen. The research process can be broadly classified in three stages:

a. research planning stage,

b. data gathering stage

c. analysis and interpretation stage.

The research planning stage involves identifying the management question from 'new event' or 'dilemma', framing it into researchable question and preparation of research design. The research question can be an analytical aid prepared to handle complex and

comprehensive problems, arise due to the emergence of new events or dilemma. The data gathering stage basically involve the exploration of various sources of information; in the earlier part of research it involves a review of existing literature while in later stages it involves using a research instrument to collect necessary information from selected sample. The analysis, interpretation and resulting stages cover preparation of instrument design, selecting the sample, analysing and interpreting the data and finding out the answer to the management question.

The Research Process Model (fig 5.1) can be viewed as an ideal picture of the research process but the different steps in real life situations can take a different sequence and therefore can occur simultaneously or in some cases change the sequence of the model showed here.

In the field of management research, the selection of research design raises an inevitable dilemma for researchers to choose between an interpretive approach covering different methodologies like ethnography, phenomenology and case studies or a positivist approach associated with inferential statistics, hypothesis testing, mathematical analysis using experimental and quasi experimental design. Spender (1996b: 72) suggests that the two methods have different objectives and to overlook the incommensurability of these approaches is to overlook the irrevocable uncertainties of the human condition and thereby everything that makes our knowing, learning and memorising processes interesting,

"The objective of positivist research is the development of a coherent abstract representation of the world out there, the presumed independent and seamless but knowledge reality in which we are embedded. The focus of interpretive research is on the ways in which attach meaning to our experience" (Spender, 1996b:72).

Therefore while a positivist approaches treats actors as objects whose behaviour can be observed by outsiders searching for general laws, interpretive methods focus on the subjective meaning attached to these behaviours. Lee (1991) argues a different viewpoint and presents a framework integrating the two approaches, demonstrating 'a particular common ground between the two of them', and 'how these two approaches to organisation research can be mutually supportive, rather mutually exclusive'.

However as Spender (1996b:71) suggests the development of knowledge can not be understood in terms of explicit or scientific method of analysis and hypothesis testing alone. The attachment of meaning, and the explication and codification of what is learned through practise and experience or learning by doing, must also be considered. Thus the strength of the qualitative approach is the ability to study participants as people and opening a window into the respondent's point of view. Such an approach is more likely to provide a better understanding of everyday experiences of managers and scientists within

large organisations. Therefore in recent years it is clearly evident that in studies of competencies or knowledge development the interpretive approach has been gaining attention as an alternative to the more traditional positivist approach (Hoskisson et al., 1999).

5.2.1. Research Design

There are clearly strengths and weaknesses with both approaches and the decision regarding research strategy must depend on the particular requirement of the research. The conditions under which research has to be conducted and the type of research question raised will furthermore influence the research strategy. The relationship between research strategies and the different parameters is drawn up in Table 5.1

The design of research methodology in this research is influenced by a number of criteria including some discussed above. According to Yin (1994), three conditions which direct the strategy of the research are,

a. type of research question posed,

b. the extent of control an investigator has over actual behavioural events and

c. the degree of focus on contemporary as opposed to historical events.

Table 5.1 Relevant situations for different research strategies (Source: Yin, 1994)

Strategy	**Form of research question**	**Requires control over behavioural events**	**Focuses on contemporary events**
Experimental	How, why	Yes	Yes
Survey	Who, what, where, how much, how many	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	**How, why**	**No**	**Yes**

Yin (1994) suggests that case studies are an ideal research strategy when a "how" or "why question is being asked about a contemporary set of events over which the investigator has little or no control. So case studies are empirical inquiries investigating contemporary phenomenon or set-off events where the boundaries between phenomenon and context are not clearly evident. This makes case study research an excellent research strategy when one wants to cover contextual conditions or when the problems investigated are embodied

in the surrounding society, implying that the interaction between phenomenon and its context is best understood through case study method.

The questions explored in this research are influenced by contemporary sets of events embedded into various contextual elements lying inside as well as outside of firms and interplay between those elements. This research is focused on the processes adopted by Indian pharmaceutical firms to develop competencies in innovative R&D as a response to change in patent law. The Indian specific contextual elements (like existing patent regulation, resources available to Indian pharmaceutical firms, institutional environment and capabilities of research institutions) need to be considered in exploring the competence development in Indian pharmaceutical firms. In this 'context' a research strategy must be selected which will allow all contextual conditions to enter into analysis and which indicates that the case study research methodology is an ideal research strategy for this research. Therefore based on the nature of the research questions, a case study methodology is used to find answers for questions raised in this research.

The multiple case study research design was adopted instead of a single case study and the cases were chosen on the basis of degree of innovativeness and their size of operation. Yin (1994:45) suggests that multiple case study designs have distinct advantages and disadvantages in comparison to single case study designs. The ideal setting for single case studies is studying the unusual or rare case or researching a critical or revelatory case. Research into all these situations is likely to involve only single case studies as that will allow the researcher to analyse phenomenon in depth. Moreover, the conduct of multiple case studies requires extensive resources and time putting a lot of stress on a single researcher. However, the evidence from multiple cases often is more compelling and over all study becomes more robust. Yin (1994) further suggests that in multiple case research design each case should serve a specific purpose within the overall scope of inquiry and multiple cases should be considered as multiple experiments – that is, to follow replication logic and not as sampling logic. In this research six Indian innovative firms are selected as cases following the replication logic.

The fact that a certain method is considered appropriate is not enough to qualify it as scientific research. Different researchers have pointed out weaknesses in case study research methodology like biased reporting of evidence or just descriptions of events. Weick (1979:38) delivers similar criticism and argues that in case study research, "many pseudo observers seem bent on describing everything, and as a result describe nothing". His suggestion for solving this problem is to "invest in theory to keep some control over burgeoning set of case descriptions". Therefore in this research theoretical framework provides the boundary to the contextual elements and helps in covering weaknesses of case

study research. Yin (1994) suggests that systematic use of a theoretical framework early in the research process will not only help selecting and designing the chosen research strategy but it is also crucial later in generalising results of the study. The theoretical framework in this research directs the selection of cases, development of priori constructs and search for empirical data.

5.2.2 Methodology strategy

In the beginning, the research did not follow a rigid design as at that stage, the focus was on acquiring an understanding or a "feel" for the subject and this inevitably put in place some restrictions, like formation of rigid hypothesis. However after the first phase of data collection and with increasing understanding of the area, the research design was firmed up for the second phase of case study research.

In the first phase the focus of the research was to explore the effect of the change in patent law on the Indian pharmaceutical industry. Therefore it focused on understanding specific changes in patent law, its implication for strategic orientation of the Indian pharmaceutical industry and the responses of Indian industry to these changes. In this phase an effort is also made to understand the institutional environment like regulatory bodies, capabilities of research institutes and evolution of the capabilities in the Indian pharmaceutical industry.

Table.5.2 Patent and licensing data on innovative firms (Source: Annual reports, 2003)

Firms	No. of patents filed for		Licensed to MNC pharmaceutical firms
	New chemical entities	New drug delivery systems	
DRL	8		3
Ranbaxy	6	4	1
Wockhardt	3		
Torrent	4		1
Lupin	2	1	
Glenmark	2		
Orchid	2		
Kopran	3		
NPIL	1		
Sun	3		

In the second phase the focus of the research was the firm level learning processes involved in the development of new competencies in innovative R&D, which implies that firms selected for the study should be innovative in R&D. In the case of Indian

pharmaceutical industry, only a handful of firms have started moving towards developing capabilities in innovative R&D (Table 5.2). This puts a restriction on the number and nature of firms chosen for the study.

In this study patents are used as indicators of firms' capabilities in innovative R&D and firms were selected on the basis of patent data. Patents have been associated with innovation and performance at many levels: region, country and company and have been used as indicators of inventing activity in several empirical studies (Hall et al., 2000; DeCarolis and Deeds, 1999; Ashton and Sen, 1988; Pakes, 1985). Further patents are widely accepted measures by policy makers and analysts (Van der Eerden and Saelens, 1991) in terms of technology strategy and competitive analysis.

Over the last decade many researchers have used patent and publication data to track the knowledge flows into the firms as well as a measure of stock of organisational knowledge (Jaffe et al., 1993; Almeida, 1996; Song et al., 2003; DeCarolis and Deeds, 1999). Patent data have received so much attention because they are systematically compiled, have detailed information, and are available continuously across time. A patent document contains a host of information like name of scientists, description of the invention, and citation to other patents and which facilitates the exploration of knowledge flows and stocks.

However there is some concern with using patent count as a measure of the stock of a firm's knowledge or use of patent citations as indicators of domestic or international knowledge transfer. First, a patent mainly represents the explicit component of the knowledge rather than tacit knowledge and therefore fails to illustrate or explain the processes underlying the transfer of knowledge or knowledge flows. Hence patent citations data can only indicate the beginning and end points of knowledge transfer.

Second, firms tend to differ in their policies towards patents. Patent literature shows that various strategic uses of patents are made by firms operating in knowledge intensive sectors like information technology and pharmaceuticals (Somaya, 2003). Much of knowledge building within the firm does not result in patenting, at the same time, not all patenting within firms represents knowledge building or knowledge flows. In the case of patenting an invention, some citations may be introduced to distinguish the invention from dissimilar ones or protect it from litigation. This implies that patents are satisfactory indicators of knowledge creation in terms of being documented knowledge but only a partial measure in case of analysing flows or stocks of organisational knowledge. While the preceding discussion suggests that there are problems inherent in the use of patents as

output measures of innovative capabilities, it also suggests that they are widely accepted objective measures of innovation.

In the case of the Indian pharmaceutical industry patent data have more limitations as publication and patents were not the priority area till 1995 due to the lack of trust in the case of the former and the lack of value in the case of the later. However it is still a creditable source of firm's innovative capabilities as well as its commitment towards innovative R&D. The estimated minimum costs of an issued patent is $12,000, which may be a fairly insignificant sum to an established pharmaceutical firm like Pfizer but to the resources limited firms in the Indian pharmaceutical industry, this expenditure would be a significant investment. For these reasons patent counts adequately capture the capabilities in innovative R&D and therefore patent data is used as an indicator of Indian pharmaceutical firms' capabilities in innovative R&D.

In the Indian pharmaceutical industry, there are a number of firms (10 to 12) who have invested in innovative R&D and have products in clinical phases (Table 5.2). However for exploring the development of competencies in innovative R&D, only those firms were selected for this study, who have filed patents in USA and India for new drug delivery systems or new chemical entities (Table 5.3). Some of the firms selected as case studies have also licensed their molecules to the multinational pharmaceutical firms proving superior capability in innovative R&D.

Table 5.3 Firms selected for the study

No.	Name of firm	Number of Patents filed for		Licensed to MNC firm
		NCE	NDDS	
1	Ranbaxy Laboratories ltd	6	4	1
2	Dr. Reddy's Laboratories ltd	8		3
3	Wockhardt pharmaceuticals ltd	3		
4	Lupin Pharmaceuticals ltd	2	1	
5	Nicholas – Piramal ltd	1		
6	Glenmark pharmaceuticals ltd	2		

Apart from analysing patents as innovative input as well as output measure, the innovation literature has also employed two other quantitative measures for studying the innovative capabilities. The other measures of innovative input include a. R&D expenditures and b. number of scientific personnel. Cohen and Levinthal, (1990) developed the concept of absorptive capacity and operationalised it in terms of an input measure, R&D intensity. However the application of these measures in this research is limited as they fail to capture the productivity of the inputs. The technological learning process is highly idiosyncratic, as technologies differ greatly in their learning requirements. The technologies have different degrees of dependence on internal knowledge generation and interaction with outside sources of knowledge or information such as other firms, consultants, capital goods suppliers or technology institutions. This affects the application of quantitative measures in analysing technological learning, specially selecting the right measures that will capture the actual learning processes or mechanisms. However at the present time, the innovative input quantitative measures identified by the innovation literature offer the best opportunity for reflecting on abilities of firms' to evaluate, assimilate and apply outside knowledge to commercial ends, i.e. absorptive capacity or capability to learn. Therefore in this research measures like R&D investment, number of scientific personnel are used as supportive tools to the main qualitative evidence.

In the case study research selection of cases and the definition of specific measures are important steps in design and data collection process. The next section discusses the various sources of data used for collecting information used in this research.

5.3 Sources of the data

The finding or conclusion in a case study is likely to be much more convincing and accurate if it is based on several different sources of information following corroborative mode. In this study, the data upon which the empirical results rest was drawn from various public and private sources. According to Yin (1994) the use of multiple data sources allows the investigator to address a broader range of historical, attitudinal, and behavioural issues and aids in achieving the triangulation of evidence in the research. Triangulation made possible by multiple data collection methods, helps in combining various sources of evidence and development of converging lines of enquiry. It provides stronger substantiation of constructs/ hypotheses and develops a robust validation to research findings (Eisenhardt, 1989). Therefore in this research, the main source of information, interviews is combined with other sources of information like observation, archival records, and reports in trade journals. For example, the two trade journals namely,

'Pharmabiz' and 'Expresspharmapulse' cover issues concerning the Indian pharmaceutical industry extensively and report regularly on the activities of various Indian pharmaceutical firms. These sources of information provided very important insights into debates surrounding various issues related to strengthening of patent law. In the case of the firms, several types of sources of data were used to collect documentary information on each firm. For instance, firm specific information was collected from annual reports, analyst presentations, conference proceedings, internal firm magazine, and if present, studies of firms by other researchers. These documents served to corroborate and enrich the evidence obtained from the main source of data collection.

The primary source of data collection used in this research is interview as it has a number of strengths as a method of data collection. Probably the most important strength is that it allows both parties to explore the meaning of the questions and answers involved. Thus any misunderstanding on the part of the interviewer or interviewee can be checked immediately. However interview technique also demands a variety of skills on the part of the researcher, often defined under the umbrella of "interpersonal skills". A considerable amount of time is also required to design the interview schedule and it is often extremely difficult to conduct interviews with key decision makers such as middle or senior managers because of their busy schedules.

5.3.1 The first phase

In the first phase of the field study, the primary information was collected by carrying out interviews with scientists working in research institutes, pharmaceutical consultants, patent experts and the president of the Indian pharmaceutical industry association. The second phase involved interviews with senior managers associated with selected firms (Appendix III).

In the first phase informal email communications with the individuals associated with the Indian pharmaceutical industry emerged as one of the most important sources of information (Appendix III). This informal communication included interactions with clinical trial researchers, academics, consultants, patent attorneys, journalists and scientists working in Indian pharmaceutical firms and it provided interesting insights into the "general current opinion" in the industry. This proved to be a very important source of precise information, although subjective in nature and generated very helpful insights into challenges of change in patent law. regulatory set up established to implement patent laws and emerging strategies of firms as a response to these changes.

Building on these informal communications, a survey questionnaire was prepared to make these electronic interactions more constructive and useful in research. Due to the

difficulties involved in sending questionnaires to India and in getting them back, it was decided to send the questionnaire electronically. The survey questionnaire was put on a website (http://elsa.open.ac.uk/admin.asp?areaid=oubs_rs) and the link was sent electronically to the participants. However sending the survey electronically to various scientists raised the problem of getting access to email IDs. The 'Indian Pharmaceutical Journal' proved the important source of the email IDs as the published papers have author's email ID. It mainly publishes papers from Indian scientists working in the pharmaceutical industry and various Indian research institutes. Therefore this proved an important and authentic source of information about scientists associated with the Indian pharmaceutical industry. The other source used for collecting the email IDs was pharmaceutical mailing lists and personal contacts. In the end the survey was sent electronically to 300 scientists working in Indian pharmaceutical firms, premier research institutes and universities focused on pharmaceutical R&D. It was also sent to the Indian scientists working in MNC pharmaceutical R&D based in US.

In the first phase, focus of the data collection was on the industry level while in second phase the focus of the collection of information was on the internal organisational practises or firm level processes involved in development of competencies in innovative R&D. In the second phase the multiple case study methodology is used and that influenced the sources and nature of data collected.

5.3.2 The second phase

The data collection in the second phase mainly involved interviews with R&D presidents, senior pharmaceutical scientists working in the six innovative Indian pharmaceutical firms. Out of six companies selected for the study three have manufacturing units along with sales and marketing operations in Europe. In all three firms, the senior manager, in-charge of Europe region is based in UK. The interviews with these managers were conducted before the field visits in India. These interviews gave glimpses into firm's future growth strategies in the generic market and aided in establishing preliminary contacts within firms. During the field visits in India, effort was made to interview at least two individuals from every firm selected for study. The first phase of field study helped in choosing the initial select group of individuals to interview in the second phase. As far as possible, in each firm the interview was conducted with senior R&D scientists or R&D vice president or director of innovative R&D project. Apart from the select group of individuals, the choice of other individuals evolved organically. Researcher began with few selected individuals and then extended list as everyone researcher spoke with recommended others who researcher should meet. Arranging the interviews in the second phase with selected

individuals proved very challenging as the whole exercise of initiating the contacts and coordinating interview appointments was managed from the UK.

The majority of the interviews were conducted by using a semi structured interview question bank and lasted about 1hour. In the beginning of the interview, researcher briefly spoke about the focus of research and then asked the individual to talk about his or her perceptions of the effects of patent law changes on the Indian pharmaceutical industry. Each interview was recorded and transcribed for analysis; however in some cases individuals did not allow the recording of the interview. So in such cases researcher took notes and then typed up a formal interview report.

In total 33 interviews were conducted, out of that 10 were conducted in the first phase and the other 23 in the second phase.

5.4 Interview and survey questionnaire

The process of framing interview questions and the survey questionnaire proved quite challenging as the nature, content and focus of the interview questions differed in both the phases.

The questionnaire used in the first phase basically focused on the implications of change in patent laws for the Indian pharmaceutical industry and strategic responses of Indian pharmaceutical firms to this change. It also covered the macro economic issues such as effect of change in patent law on industry structure, market structure and emerging challenges.

In the second phase of the field study the focus of the data collection was firm level learning processes involved in development of competencies in innovative R&D. In this phase, the theoretical framework directs the areas of investigation and guides preparation of the priori specification of constructs. Due to the inherent difficulties in studying 'processes', a question bank was prepared using concepts from the theoretical framework (Appendix IV). The interviews generally focused on different organisational learning processes or activities involved in acquisition, assimilation, transfer and integration of knowledge. Interviews also covered the questions regarding how the firms have built the prior knowledge and its relevance in innovative R&D. It referred to the nature of the firm's existing base of technical and organisational knowledge, processes involved in creation of the existing knowledge base and relevance of the existing knowledge base to innovative R&D. The interview questionnaires from other researchers like Madanmohan and Krishnan (2003) and Dutrénit (2000) who have explored similar issues of adaptation and change associated with capability development also proved helpful in structuring the nature of interview questions. In the interview individuals were asked about learning

mechanisms and organisational arrangements promoted and established to develop capabilities in innovative R&D. It referred to the different organisational practises involved in management of innovative pharmaceutical R&D identified by Henderson and Cockburn (1994) as measures of competencies. These measures include organisational processes involved in the organisation and management of R&D like project management structure, review of research, resource allocation, incentives system, nature of research teams and assignment of personnel to research teams. Other areas of focus in interviews were the use of collaborations with universities, research institutes by firms, nature of those collaborations and mechanisms of the interaction. This list of learning mechanisms and organisational arrangements was added to question bank and from which a set of questions formed the semi structured questionnaire used in each interview.

Although the theoretical framework guided the data collection and provided the contextual boundaries, the care has be taken to include and explore any critical issues which are outside the boundaries of theoretical framework but have implications for answers to research questions

Survey questionnaire used in the first phase of the research was based on the other questionnaires used by different researchers like Birkinshaw (2001), Ingelgard et al.,(2002), Thombke and Kuemmerle (2002), Visalakshi and Sandhya, (2000) to study various issues related to R&D in the pharmaceutical industry. Major parts of the survey questionnaire also evolved in the informal communication with experts and scientists working in the Indian pharmaceutical industry. Survey questionnaire focused on exploring opinions of the individuals regarding effect of change in patent law on reverse engineering R&D, major constraints in moving towards innovative R&D, relevance of knowledge accumulated in reverse engineering R&D to innovative R&D, capabilities of Indian research institutes and universities and strategic responses of Indian pharmaceutical firms to changes in patent law (Appendix V). Using an approach similar to Birkinshaw (2001), it explored the opinion of individuals regarding difficulties associated with learning in pharmaceutical R&D. The survey helped in understanding the complexities involved in developing innovative R&D capabilities in the pharmaceutical industry. Based on the Thombke and Kuemmerle (2002) questionnaire, it asked the degree and direction of change in value / importance of the various pharmaceutical R&D issues for the Indian pharmaceutical industry from 1995-2003. This provided insights into transformation or changes into R&D strategies in the Indian pharmaceutical industry. Finally questionnaires explored technical competencies in terms of in-house capability of Indian pharmaceutical firms to perform various scientific processes in innovative R&D like basic genome research, identification of target molecule and clinical research. The last section of the

questionnaire asked participants to identify innovative firms in Indian pharmaceutical industry.

A five point Likert scale is used in the survey questionnaire and collected data was analysed by using non parametric tests. It is summarised by using a mode and bar charts were used for displaying the distribution of observations.

5.5 Analysing the data

The interviews along with other sources of information contributed to this story of learning processes involved in developing competencies for innovative R&D in Indian pharmaceutical firms. In this research the qualitative analysis software, Atlas.Ti is used as a tool for data organization and standardisation to facilitate its analysis. Data was standardised and transformed into workable units by using techniques like common codes and preparing displays of commonly coded data segments which Miles and Huberman (1984) refer to as key data reductive techniques for transforming data into workable units.

In management research, analysis of data forms the pivotal bridge from the information to the final insights of the research and so, represents the 'heart' of building theory from case studies (Eisnehardt, 1989). Therefore in this research a systematic approach to data capture and analysis was taken to ensure a clear 'audit trail' between the data and the conclusions that were distilled.

Eisenhardt (1989) suggests 'within case analysis' as the key step in multiple case study data analysis, as the individual case analysis helps in identifying patterns of idiosyncratic interaction of factors specific to respective firm before looking for patterns across cases. Cross case analysis helps investigators to go beyond initial impressions and improves the likelihood of accurate and reliable theory, that is, a theory with close fit with data. Therefore in this research, each firm was examined as an entity in its own right before case cross analysis was undertaken. The 'within' as well as 'cross case' analysis of the empirical evidence was carried out by using various analytical techniques like pattern matching (Yin, 1994) and by building of analytical tables (Miles and Huberman, 1984).

Yin (1994) suggests that for case study analysis, one of the most desirable strategies is to use pattern matching logic. In this research, strategy of pattern coding is used to identify the processes involved in transformation of capabilities within and across the firms. In analysis first level coding is used as a device for summarising segments of data while pattern coding is carried out by grouping those codes into a smaller number of overarching themes or constructs. The transcripts were analysed by coding the different internal organisational processes around the transformation issues within each firm. The theoretical framework provided broad categories for classification of the data and various pattern

codes are classified under those broad categories. Then the replicating patterns of internal organisation process representing the learning mechanisms and organisational arrangements adapted by firms' to facilitate the development of competencies in innovative R&D were identified. Miles and Huberman (1984: 67) suggest pattern codes are explanatory codes, ones that identify an emergent theme, pattern or explanation that the site suggests to the analyst. They act to pull a lot of material together into more meaningful and parsimonious units of analysis. The replicating patterns were supplemented by secondary data which was collected from industry journals, industry association publications and annual reports of firms. The observed patterns in Indian pharmaceutical firms were then compared with the theoretical patterns identified from the framework to find the similarities and differences between them. Yin (1994) suggests that if the patterns coincide with empirical patterns, the results can help a case study strengthen its internal validity. Although he also argues that at this point in the state of the art, the actual pattern matching procedure involves no precise comparisons and this lack of precision allows for some interpretive discretion on the part of the investigator.

Table 5.4 Cross case analysis

Learning process and mechanisms	Criterion	RAN	DRL	NPIL	WOCK	LUP	GLE
Acquisition of knowledge Assimilation of knowledge Mechanisms of knowledge transfer Integration of knowledge	Present Or absent Nature of presence: Strong or Moderate or Weak						

After analysing each firm, the cross case analysis of learning mechanisms and organisational arrangements is carried out to explore the inter-firm differences in processes involved in development of competencies in innovative R&D. According to Esinehardt (1989) one of the tactics is to select categories or dimensions, and then look for within group similarities coupled with inter-group difference. In this research an extension of this tactic is used by preparing analytical tables (Miles and Huberman, 1984) of all codes at once and classifying each firm on those criteria (Table 5.4). So in this research different codes were organised in four categories like mechanisms of knowledge acquisition, knowledge transfer, knowledge integration and knowledge assimilation. The firms were classified in terms of presence/absence of particular learning mechanism /process and

intensity of support for these learning processes. Therefore firms were classified, first on the basis of whether that mechanism is present or absent in that firm and then each firm was classified on the basis of intensity of support using criteria of strong, weak and moderate. This was identified through perceptions, comments, and assessments expressed by different interviewees, by doing a systematic search about firms' records in information collected from secondary sources, top management support to learning process identified from annual reports, and how the learning process operated (e.g. incentive systems for scientist, nature of research collaborations). Thus inter-firm differences in learning processes and its impact on capability development are examined.

A case study report with key findings was sent to a key informant in each firm for a review. This key informant provided additional details and corrected inaccuracies.

5.6 Writing the case study

The case study is written by following a linear analytic structure. The evidence is presented in two ways focusing at industry and firm level:

1. Chapter 6 and Chapter 7 present the case of the Indian pharmaceutical industry. Chapter 6 describes the institutional environment and impact of change in patent law on the strategic orientation of the Indian pharmaceutical industry. It discusses the learning processes associated with evolution of capabilities in the Indian pharmaceutical industry by presenting the capability creation model.

2. Chapter 7 discusses a historical evolution in sample firms' technological capabilities and presents learning processes involved in development of innovative R&D capabilities as a response to strengthening of patent law in each firm. The narrative is supported by including the description of innovative input measures like R&D investment, number of personnel working in R&D.

3. Chapter 8 analyses, interprets and discusses the learning processes associated with development of innovative R&D capabilities within each firm by linking it with various mechanisms identified in the theoretical framework. This chapter also presents inter firm differences and difficulties involved in development of innovative R&D capabilities.

5.7 Summary

This chapter discussed the methodology adopted in this research. It explained the rationale for choosing a phase based or progressive methodology and using case studies as the main

research methodology. It explained in detail use of different sources of informat different techniques used to collect necessary data. This chapter concluded discussion on the method employed for the data analysis.

The next chapter describes the important characteristics of various learning mechanisms prevalent in the Indian pharmaceutical industry. Then it discusses the results of the first phase of data collection, covering the impact of TRIPS agreement and subsequent transformation strategies in the Indian pharmaceutical industry.

Chapter 6

THE INDIAN PHARMACEUTICAL INDUSTRY

This chapter describes the broad characteristics of the Indian government's industrial and technology policies and reviews its role in shaping the Indian pharmaceutical industry. It also presents the impact of the TRIPS agreement on R&D capability development process in Indian pharmaceutical firms and discusses its implications for the existing industrial and market structure. Finally by using the 'capability creation model' this chapter discusses the learning processes and stages involved in accumulation of technological capability in the Indian pharmaceutical industry.

6.1 Introduction

National technological capability is a complex mix of skills, experience and effort that enables a country's enterprises to efficiently buy, use, adapt, improve and create technologies (Lall, 2000). According to Forbes and Wield, (2002) much of the difference between countries that developed rapidly and those that have developed more slowly is a difference in indigenous technology capability and how that technology capability is developed and used. While the firm remains the fundamental unit of technological activity, the non market system of inter firm linkages, ways of doing business, and the web of supporting institutions affect significantly how firms interact with each other and the efficacy with which they exchange the information needed to coordinate collective learning and indigenous technology capability development. The main incentives that affect the investments in technological capabilities arise from micro economic environmental issues like trade policy, domestic industrial policies and domestic demand along with factor markets like availability of skills, finance and the nature of the supportive institutional base (Lall, 2000). In this context, India presents an interesting example of a country with an immense economic potential, cultural diversity and income inequality among its population. Over the years the Indian economic policy framework has moved from a centrally planned economy to a market dominated export oriented economy and in the process, impacting on industrial growth, human resource skills building and institution development. It now ranks among the ten largest industrial economies and amongst the five largest agricultural economies.

In the post independent era, Indian economic and industrial policy was dominated by an import substitution ideology where state interventions and regulations played a key role in

directing firm and national level indigenous technology capability development. It was considered essential that the public sectors occupied the economy's 'commanding heights' and the state focused on building the 'temples of sciences' in the form of universities and higher education institutes. However, in 1990 the balance of payments crisis triggered major changes in the Indian government's industrial and economic policy orientation. From a relatively inward looking set of policies that was in place till the end of 1980s, the policy regime adopted in 1991, sought to break down the walls of protection within which the Indian industry had developed in the past (Bhagwati,1993). The existing pharmaceutical industry in India is in many ways a product of micro economic environment shaped by state regulations and interventions. The Indian pharmaceutical industry has come a long way from importing bulk drugs to exporting formulations to highly regulated markets in the developed world. This movement of the Indian industry involved different learning processes and stages and which are discussed by constructing the 'capability creation model (Fig.6.2). This model maps these processes and stages involved in technological capability accumulation on a pharmaceutical value chain. It also provides a historical background to the current industry situation and presents the nature of existing knowledge bases and capabilities in the Indian pharmaceutical industry.

Section 6.2 presents the changing contours of Indian industrial and technology policy and discusses its role shaping the Indian pharmaceutical industry through Indian drug policy. Section 6.3 analyses the impact of TRIPS on Indian drug policy and the strategic orientation of the industry. Section 6.4 presents the capability creation model in the Indian pharmaceutical industry and discusses the learning processes involved in technological capability accumulation at the industry level. Section 6.5 concludes the chapter.

6.2 The changing contours of Indian industrial and technology policy

This section presents the characteristics of India's industrial policies and their role in the growth of the pharmaceutical industry. It also discusses Indian drug policy, R&D institutions and market structure and their influence in shaping the Indian pharmaceutical industry.

6.2.1 The Indian Industrial Policy

In post independent era India's industrial growth was shaped by industrial policies based on the import-substitution model and which to a larger extent focused on indigenisation. The Indian government shaped and directed objectives of self reliance through various policies focused on strictly regulating and restricting imports of the technology to protect the local technical effort by Indian firms. Forbes (1999) points out that from 1956 onwards

Indian industrial policy had two basic tenets: industrial targeting and licensing, and foreign exchange control over all the transactions. This resulted in the direct control of imports of capital, intermediate and consumer goods. The main elements of industrial policy contained,

a. protection from import competition,

b. over valued exchange rates,

c. restrictions on the inflow of technology and foreign direct investment and

d. industrial licensing.

The Indian government introduced a quota system for the import of goods and levied custom duties on imported products, in some cases as high as 150 to 250%. This restricted the effective inward transfer of imported technology and by that affecting an important source of technological learning for Indian industry. Lall (1987) suggests that imported technology provides the most important input into technological learning in developing countries. However, the effectiveness of modes of technology transfer depends upon the policy setting. For example, even for accessible technologies, externalised modes can be wasteful if used in a protected setting to achieve technological self reliance rather than as in the case of Japan or Korea, to supplement strong local design and development efforts. Desai (1989) points out that the India's policies of regulating the transfer of technology led to less technology coming in than should have and less use made of technology that did come in than should have. Thus Indian industrial policies certainly limited the import of technology. This led to the development of local industries that focused on indigenisation to produce everything locally and as a result, the Indian industrial firms developed similar technological capabilities and products.

Indian industrial policies were also characterised by a significant growth of public sector investments in areas outside core infrastructure sectors and strict regulation of the inflow of private capital and technology into economy (Forbes, 1999). The Indian public sector comprised more than 5000 factories, absorbing two thirds of fixed capital investment in the factory sector. Except very few, most public sector units generated large losses each year. The Indian government controlled the inflow of private investments into the economy through the Foreign Exchange Regulation Act (FERA). In 1973 the Indian government adopted the FERA to reduce the share of foreign equity in enterprise registered in India. FERA allowed a foreign equity holding up to 40% in any enterprise registered in India. other than those of strategic importance. This regulation forced MNC firms to reduce equity holdings to 40% and which resulted in the departure of leading MNC firms like IBM from India. The measure like import tariffs and industrial licensing, discouraged market competition and several Indian industrial sectors became crowded by a huge

number of small firms, each doing the same thing. Even in the sectors which were characterised by a few larger firms there was little incentive to innovate. The expansion beyond licensed capacity was forbidden and therefore there was little drive for manufacturing efficiency and process innovations.

However, the Indian government's industrial policies also forced industrial firms to conduct much technical effort through in-house learning, which led to the development of firm level technological capabilities. The Indian industry built substantial technical abilities by learning to make everything locally and resulted in the development of a range of intermediate components of some sophistication. The indigenisation activity forced the occurrence of much technical effort in firms and this resulted in the development of a wide ranging production base. Thus some firms used the protection policies to build useful technological capabilities, however much of the Indian industry was characterised by widespread inefficiency and product obsolescence. Lall (1984) summarises the technological capability development in pre 1991 era by pointing out that India's industrial performance signifies that it had developed the "broadest and best developed technological capabilities in the third world", whereas on other hand, India had performed poorly in terms of "industrial growth, the expansion of manufacturing exports, the absorption of industrial labour and introduction of innovative products in foreign or domestic markets".

The liberalisation of the Indian economy started in the early 1980s with the Indian government adopting policies which substantially eased the import of industrial technology. The balance of payments crisis in 1990 gave momentum to economic liberalisation and led to changes in the Indian government's industrial policy. From 1991 there has been shift away from import substitution and other closed economy approaches of industrialisation towards the industrialisation with an open–economy and export promotion approach. In the decade of 1990s, the Indian government abolished industrial licensing, removed import quotas on non consumer goods and took various measures to attract foreign direct investment. The import tariffs on industrial goods were gradually reduced every year from 1992; 125% in 1992, 85% in 1993, 65% in 1994, 50% in 1995 and 40% in 1996. By 2004 the average industrial tariff was reduced to 25%. The change in policy led to the entry of products of international quality and every major international player now competes alongside Indian firms, thereby dramatically increasing competition in Indian markets. After the liberalisation, Indian economy has consistently shown a GDP growth rate of about 6 % per annum during 1992-2004. The Indian corporate sector has responded proactively to the growth opportunities afforded by liberalisation. Lots of Indian firms have improved their operational performances either by a. increasing their efficiency, b. focusing on technology licensing or c. substantially increasing their R&D investments

(Forbes, 1999). Many Indian firms realised that they had no choice but to improve efficiency in order to be able to operate in an open domestic market. Several industrialists now perceive exports as being both necessary and attractive. Some firms have moved into the overseas markets while others have internationalised their operations by starting or acquiring manufacturing units in various countries.

The next section discusses the Indian government's science and technology policies and their impact on technology capability development.

6.2.2 The Indian science and technological policy

In the post independent era, Indian policy makers viewed scientific research as an imperative activity for technological progress and put an extensive effort into creating a scientific workforce and institutions. The objective of self reliance also dominated the Indian government's science and technology policy and leading to the establishment of a number of state owned research institutes all over the India.

Forbes and Wield (2002) point out that based on the belief that technology and industrial development will automatically follow the scientific research, the Indian government invested in building research institutes. Since 1950s the Indian government has set up a vast and diversified network of R&D institutions under the umbrella of the Council of Scientific and Industrial Research (CSIR). CSIR consists of 43 national laboratories employing about 10,000 highly qualified scientific and technical personnel. The Indian government funded and conducted over 80% of formal R&D through this network of state owned R&D institutions. The laboratories of CSIR conducts research into diverse socio-economic sectors and covers a wide canvass of scientific disciplines ranging from microbiology, chemistry and genomics to areas such as oceanography, microelectronics, and geophysics.

The literature on technology capability development stresses the significance of research institutions for supporting enterprise efforts to develop their knowledge and capabilities. According to Bell and Pavit (1993) public or quasi public institutions (universities, government, research laboratories etc) in developed countries complement industrial firms; their out put of knowledge are inputs for these firms. However, in India this complement between industry and institutes never evolved due to the differences in their research focus. The major objective of the work done in the Indian R&D institutes was indigenisation; so if some thing is imported, then find the process or mechanism to develop it locally. These laboratories never benchmarked their activities to global players, as it was not necessary or required to do so (Bowonder and Richardson, 2000). The activities in these labs marginally focus on the commercialisation as the research orientation and activities in these

laboratories differed from the needs of local industry. As the National Chemical Laboratory's business development manager explains,

"In the past, industry and research institutes operated in the protected environment; a kind of monopolist environment. It was seller's market and when you are in seller's market, you have no incentive to innovate. Research institutes like us who are working on cutting edge science had no takers for what we were doing. There was mismatch between our output and what industry wanted".

In India even a science based industry like pharmaceuticals which is globally characterised by strong industry-academia linkage, lacked the web of such linkages. A pharmaceutical consultant comments on the experience of pharmaceutical industry's linkages with research institutes,

"In reality while the institutes outside the industrial sector have excellent scientists, they lack two important traits a. sense of what to develop which could be commercially interesting and b. the ability to evaluate the economic viability of the processes developed. Industry until recently have also been wary of the public institutes since they were afraid that confidentially will not be maintained under the structure prevailing in the institutes".

Thus the crucial link of technological progress; industry–academia linkages didn't evolve in India and therefore the investment by Indian government in R&D did not help these institutes to emerge as a source of technology.

According to Forbes (1999) for most firms in India, the major source of technology was the informal transfer of technology either through market mediated modes (subcontractors) or non market mediated modes (reverse engineering or duplication). The R&D in Indian industrial firms had a shorter horizon compared to industrial countries and activities were largely involved trouble shooting and technical services (Desai, 1985). The content of R&D in the industry became primarily the development of local raw materials, component suppliers and substituting an item where the exact item was unavailable by developing a local manufacturing process. Desai (1985) points out that out of thousands of industrial producers, less than 4000 got permission to import technology; the rest bought, borrowed or reverse engineered technology within the country. Indigenisation as a main objective also led to the neglect of crucial factors associated with the product development such as quality and cost involved in developing the product indigenously. Forbes (1999) suggests that whether the product compared with what was internationally happening in terms of technology, or was sold at a price that reflected international competitiveness was of no concern at all. To a larger extent, the job of R&D in private and public sector units was confined to the indigenisation of the next product and not to the improvement of the existing product or its manufacturing process.

However, the liberalisation of the Indian economy in 1991 and signing of the TRIPS agreement brought changes in the Indian government's science and technology policies and forced CSIR labs to become customer oriented and market responsive. In India the traditional measure of R&D funding; the public support mechanisms like grants and subsidiaries, were changed to private- public support mechanisms.

According to Sikka (1998) now national laboratories of the CSIR as well as prestigious technical institutes have been instructed by the Indian government to earn at least 30-50 % of their R&D expenditure by commercialising the indigenously developed technologies and by the generation and utilisation of patents, instead of pursuing R&D just as an academic exercise. As a response to new challenges, CSIR introduced two major policy thrusts:

a. to promote the quest for patenting in Europe and US as a mean of engendering a strong desire to undertake R&D and to innovate;
b. to increase the commercial orientation of industrial research, thereby making the CSIR less dependent on budgetary support.

The new policy thrusts have resulted in increasing the collaborative ventures between CSIR institutes and Indian industrial firms. NCL's business development manager suggests,

"look at automobile sector, even Indica, Victor are the products of Indian R&D. They survived in the competitive market. They obviously (companies) interact with the Indian research institutes; they do not have all the capabilities in-house. They will go to IIT (Indian Institute of Technology), work with professor on design and all that goes on".

In the post 1990 economic environment, the share of private sector spending in R&D has also increased and by 2000, the in-house share reached 35% with almost all growth taking place in the private sector (Forbes and Wield, 2001). Desai (1980) points out that in 1958 virtually all industrial research was being done in CSIR laboratories.

In the post 1990 era, the research institutes are contributing towards increasing Indian firms' competitiveness by helping these firms to improve existing products or to develop new products. According to the NCL's business development manager,

"research institutes role will increase because all the firms in industry have to do R&D and they can not afford to have all the capabilities in-house. They may keep some core competencies but rest of them they have to acquire from outside".

The CSIR's current global orientation is also evidenced by the substantial rise in the number of patents filed and granted in the US. Over the 1995-99 period, the number of patents filed by CSIR rose by 90% to 112 in 1998 (Sikka, 1998).

6.2.3 The role of industrial and technology policy in growth of Indian pharmaceutical industry

The movement of Indian industrial policies from inwardly oriented measures to breaking down walls of protection had enormous effects on the evolution of the Indian pharmaceutical industry. Since independence the pharmaceutical industry in India has mainly evolved through three phases, each characterised by different policy regimes and industry's response to those policies. The first period was prior to 1970, when the industry was relatively small in terms of its production capabilities. The second period is the decade and a half phase spanning from the 1970s to the beginning of the 1990s, a period during which the output of the industry grew remarkably. In the third phase of expansion, from 1990s onwards, the pharmaceutical industry grew more than three times faster than it did during the 1980s.

The decade of the 1970s was the turning point in the development of the Indian pharmaceutical industry. In the pre 1970 era foreign firms had a disproportionately high share in the total Indian domestic pharmaceutical production. These firms together produced 42% of bulk drugs and formulations and produced about 38 % of all bulk drugs produced by the Indian industry (Indian Drug Policy, 1978). To encourage the growth of the domestic industry and reduce dependence on foreign pharmaceutical firms, the Indian government took forward three key policy initiatives in the 1970's. The first policy initiative was the Drug Price Control Order (DPCO) by which the Indian government sought to control the prices of drugs. The second was the adoption of a new weak patent act which Indian parliament passed in the 1970 but became effective in 1972. The Indian Patent Act, 1970 was the most conscious attempt by the Indian policy makers to improve the terms of accessing international intellectual property. The third initiative was the adoption of a drug policy in 1978 which proposed an elaborate use of the industrial licensing system to organise capacities in keeping with the broad objective of capability creation in domestic pharmaceutical firms. The Foreign Exchange Related Act (FERA) also influenced the working of MNC pharmaceutical firms in India as these firms had to bring down their foreign holdings to 40%.

6.2.3a Drug Price Control Order

Strict price control regulation was introduced with the 1970 Drug Price Control Order to make drugs accessible and affordable to the poor population. The Drug Price Control Order was introduced at the beginning of the 1970s with the aim of fulfilling two objectives. The most obvious objective was to ensure equitable distribution of drugs and make them available at a reasonable price. The second objective was to create an incentive

structure for domestic producers so as to encourage them to produce new formulations at cheap prices through efficient process development. Besides covering all formulations, DPCO also gave the Indian government power to fix the minimum price of essential bulk drugs. Therefore, the price control became applicable to all the bulk drugs and formulations available in the Indian domestic market.

In 1979 a modified DPCO was adopted in which the number of drugs under the price control was brought down from 347 to 163. The DPCO, 79 also introduced three categories to classify the drugs for price control;

a. Category I – life saving formulations,

b. Category II – highly essential formulations

c. Category III – drugs excluded from price control.

The important change introduced by the DPCO, 1979 was that all producers belonging to the small scale sector, whose annual turnover was less than Rs.10 million, were explicitly exempted from price control. This exemption was adopted to protect the small scale sector in the pharmaceutical industry and proved to be one of the key reasons for the presence of a large small scale sector in the Indian pharmaceutical industry.

6.2.3b The Patent Act 1970

The weakening of patent laws, through the Patent Act 1970 helped Indian policy makers in designing the patent system that ideally served India's development and healthcare needs. The historical account of the pharmaceutical industries in Europe, Japan and US suggest that before shifting to the strong patent regime these countries used the weak IPR regime to encourage and protect the domestic industry. Evidence also suggests that the strong patent regime is an important incentive for innovators but it is not enough to promote innovative culture especially where the market for innovation is small and capabilities for innovations are low or absent. The Indian government adopted the process patent regime in keeping with the argument that such a regime would encourage innovations and development of local technological capabilities. The other key issues that determined the adoption of the weak patent system were the high prices of drugs and abuse of the patent monopoly by foreign patent holders. The provisions of the Patent Act 1970 restricted the right of patent holders in the area of pharmaceuticals and allowed firms to produce drugs with alternative processes.

6.2.3c Drug Policy

The first step towards evolving a comprehensive policy regime for the Indian pharmaceutical industry was taken through the setting up of the Hathi Committee in 1974.

The recommendations made by the Hathi Committee in its final report presented in 1975 formed the basis of the drug policy announced by Indian government in 1978. This policy had five broad objectives. The first objective was to develop a strong Indian sector in pharmaceutical industry with the public sector playing a leading role. The second was to channel the activities of foreign firms in accordance with national priorities and objectives. The third was to deepen the production base of the domestic industry by ensuring that the production of drugs took place at the most basic stage possible. The fourth objective of the drug policy was to encourage indigenous R&D and finally, drugs should accessible to all at reasonable prices.

The 1978 Drug Policy provided incentives to the Indian drug manufacturers by making a number of relaxations in the provisions of the Indian industrial policy. These firms were granted licenses, which allowed them to produce formulations (drug in tablet or dosage form) up to 10 times the value of bulk drugs. Foreign firms faced a relatively strict regime as regards to the production of formulation. To ensure that the production of drugs in India took place from very basic stage, the drug policy imposed three conditions on the foreign drug firms intending to operate in India. The conditions were:

a. the ratio between production of bulk drugs and formulations that these firms could maintain in their final output was 1:5, as against 1:10 allowed to the Indian firms,

b. licenses to the foreign firms were provided only if the firms agreed to supply 50% of their production of bulk drugs to non-associated formulators and

c. foreign firms producing formulation based on imported bulk drugs and intermediates had to start manufacturing from a basic stage within two years.

The policies applied to foreign firms were thus aimed at utilising strengths of these firms for creating linkages within the industry and increasing industry's downstream capabilities. While the DPCO affected the growth of the Indian pharmaceutical industry in negative way, the Patent Act of 1970 provided the initial impetus for the industry to take firm roots in India. These policy initiatives reduced the entry barriers for small scale entrepreneurs and provided these entrepreneurs special incentives such as exemption from price controls. These initiatives encouraged entrepreneurial activity among Indian managers and scientists, who set up small scale manufacturing units. This led to emergence of an industry populated by a large number of small firms. The Indian pharmaceutical industry thus consists of large sized Indian private/public sector, MNC pharmaceutical firms and lots of small scale private sector firms. The second half of the 1980s shows a remarkable increase in the output of the industry in terms of bulk drugs and formulation production performance. The latter half of the 1980s was clearly the one in which Indian pharmaceutical firms consolidated their position in the domestic market.

Table 6.1 Growth in Indian pharmaceutical industry during the 1980s (Source: OPPI,2001)

	Year	Bulk drugs Rs. Million	Formulations Rs. Million	Total
1	1980-81	2400	12000	14400
2	1981-82	2890	14340	17230
3	1982-83	3450	16600	20050
4	1983-84	3550	17600	21150
5	1984-85	3770	18270	22040
6	1985-86	4160	19450	23610
7	1986-87	4580	21400	25980
8	1987-88	4800	23500	28300
9	1988-89	5500	31500	37000
10	1989-90	6400	34200	40600

This era of protected environment, intensive competition among domestic firms and strong emphasis on reverse engineering, on one hand created strong capabilities in reverse engineering R&D, however it also generated some negative characteristics, which dominated 'ways of working' in Indian pharmaceutical firms. The extensive focus on reverse engineering R&D allowed Indian pharmaceutical firms to build a strong knowledge base in process R&D but this also has resulted in the development of an insular technical knowledge base. Reverse engineering does not require specialised investment in R&D since firms cannot and are not required to generate new knowledge. Due to the intense focus on reverse engineering R&D, Indian firms built strong capabilities in organic and synthetic chemistry, but other areas of innovative pharmaceutical R&D like medicinal chemistry and biology remained neglected. This led to the development of an insular knowledge base in these firms.

The reverse engineering focused R&D also prevented the development of communication channels like publication and conferences, which help in creating links with a larger scientific community. NPIL R&D director points out,

"when you are doing reverse engineering there are very few things which can be put in the publication. Indian pharmaceutical companies were working on the processes so there was no need as most R&D work was imitative in nature".

The weak patent law also affected the Indian pharmaceutical industry's regulatory management capability, a key capability required to operate in advance markets. Due to weak patents laws, patents could neither protect any information nor create any value for

Indian pharmaceutical firms. This is reflected in the negligible publication and patenting activity by Indian pharmaceutical firms in this era, preventing development of basic IPR management capability.

The other major impact of the protective environment was the lack of any innovative activity in Indian pharmaceutical firms. Protectionism provided the Indian pharmaceutical industry with a domestic market free of competition and as a result there was no need to be innovative or seek foreign markets. The weakening of the patent act and the drug price control order of the 1970s forced MNC pharmaceutical firms to reduce their operations in India, thus providing a space for Indian domestic firms to expand in the local market. This provided Indian firms with a domestic market which was large in volume but small in value. The lack of enough value in the Indian market proved detrimental to the emergence of innovative R&D in Indian pharmaceutical firms. Lall (2000) points out that the nature of domestic demand plays an important role in influencing national capabilities as the size of the domestic market influences the kind of activities that can be undertaken. In the case of India, the income level of the large population is low with less than 4% of the population covered by medical insurance and therefore drug expenditure is directly paid by consumers (Redwood, 1995). As a result, Indian consumers are more price-sensitive compared to consumers in developed countries and quicker to switch to cheaper alternative therapies (Lanjouw, 1996). NCL's head of new drug delivery research points out,

"In India people will say alright I am fine taking 4 tablets a day because I am spending only Rs. 8. I don't have to spend Rs. 12 (for superior product). So market does not develop for technologically innovative products".

The attitude among the Indian population and entrepreneurs that imported technology is better and can not be improved locally, was also one of the factors that prevented innovative activity in Indian pharmaceutical firms. Forbes and Wield (2002) suggest that there are many variables that go into the crucial issue of building an innovative national culture and points out a most important barrier is a subtle combination of "not invented here" and "foreign is better". The combination of these two syndromes results in attitudes and practices against fiddling with the imported technology; a feeling that imported technology can not be improved on locally. According to Managing Director of Cipla scepticism among Indian doctors about the ability of Indian pharmaceutical firms to improve technology is one of reasons for lack of innovative orientation in Indian pharmaceutical industry. He elaborates,

"Essentially, what Indian doctors say is that if this product is as good as you say it is, then why haven't companies like Pfizer and Glaxo brought it out before you? It's a mindset. It takes more than 50 years to get out of that" (Hamied, 2002).

Thus the nature of domestic demand provided little incentive for Indian pharmaceutical firms to invest in innovative activity and affected the development of innovative culture in these firms.

During 1986-87 the policy regime for the pharmaceutical industry in India was revised. The new DPCO was introduced which further reduced the drugs under price control to 145. In case of formulations two categories of drugs were kept under the price control regime;

a. Category I – drugs used in the National Health Programme monitored by Ministry of Health and

b. Category II – essential drugs identified by a group of experts.

The aggressive transformation of the Indian industrial policy orientation in 1990 also influenced the Indian government's pharmaceutical industry regulation policy. In 1994 the government introduced modifications to the existing drug policy and adopted the new DPCO; both measures were aimed at freeing the industry from the limitations imposed by government regulations.

The Drug Policy 1995 abolished licensing policy for all drugs except drugs under the three categories

a. identified bulk drugs which were to be the exclusive preserve of the public sector units,

b. bulk drugs produced by using recombinant DNA technology and

c. bulk drugs requiring in-vivo use of nucleic acids.

The drug policy also removed conditions which stipulated mandatory supply of a percentage of bulk drug production to non-associated formulators. The new drugs developed through indigenous R&D were put outside of price control for a period of 10 years from the date of their commercial production. DPCO 1995 reduced the number of drugs under price control to 74 while the scope of price control was shortened to only two categories:

a. those in which there were at least 5 bulk drug producers and 10 formulation producers, with none having market share exceeding 40 %, and

b. genetically engineered drugs produced by recombinant DNA technology.

In 1999, the reservation of 5 drugs for manufacture by the public sector only was abolished, thus opening them up for manufacture by the private sector also. Foreign investment through the automatic route was raised from 51% to 74% in March, 2000 and the same has been raised to 100% in 2002. Automatic approval for 'Foreign Technology Agreements' is being given in the case of all bulk drugs, their intermediates and formulations except those produced by the use of recombinant DNA technology, for which the procedure prescribed by the government has to be followed. The Indian government

introduced some incentives in form of tax exemptions for firms which are investing in R&D. The expenditure on filing patents, obtaining regulatory approvals and clinical trials besides R&D in biotechnology now includes in the R&D expenditure.

The changed policy regime in the decade of 90s transformed the Indian pharmaceutical industry's 'ways of working' and saw the strongest performance of the industry on several fronts. The important feature of this performance was that it came at a time when the industry faced serious challenges due to changes in Indian industrial policies. The production of bulk drugs increased from Rs.7300 million in 1990-91 to Rs.37770 million in 1999-00 while production of formulation went up from Rs. 38400 million to Rs. 159600 million during the same period (Table6.2). The share of bulk drugs in the total drug production went up from 16.0 % in 1990-91 to 19.1 % in 1999-00.

Table 6.2 Growth in Indian pharmaceutical industry during the 1990s (Source: OPPI, 2001)

No.	Year	Bulk Drugs Rs. Million	Formulations Rs. Million	Total
1	1990-91	7300	38400	45700
2	1991-92	9000	48000	57000
3	1992-93	11500	60000	71500
4	1993-94	13200	69000	82200
5	1994-95	15180	79350	94530
6	1995-96	18220	91250	109470
7	1996-97	21860	104940	126800
8	1997-98	26230	120680	146910
9	1998-99	31480	138780	170260
10	1999-00	37770	159600	197370

The industry turned into a net foreign exchange earner during the 1990s and throughout the 1990s this surplus had been increasing. Total exports have gone up from Rs.7848 million in 1990-91 to Rs.68520 million in 1999-00 (Table 6.3). The increasing share of formulation drugs in export suggests the shift in technological capabilities, specifically the transformation of manufacturing facilities to international standards.

Table 6.3 Indian pharmaceutical exports (Source: OPPI, 2001)

No.	Year	Formulations Rs. million	% of Total	Bulk drugs Rs. million	% of total	Total Rs. million
1	1980-81	351	(76)	112.8	(24)	463.8
2	1981-82	693.4	82	154.5	18	847.9
3	1982-83	546.0	83	113.4	17	659.4
4	1983-84	614.6	77	184.6	23	799.2
5	1984-85	995.0	77	292.5	23	1287.5
6	1985-86	1065.9	76	333.6	24	1399.5
7	1986-87	1021.2	54	871.6	46	1892.8
8	1987-88	882.5	39	1397.1	61	2279.6
9	1988-89	1572.9	39	2428.7	61	4001.6
10	1989-90	3142.0	47	3505.0	53	6647
11	1990-91	3714.0	47	4134.0	53	7848
12	1991-92	5585.0	44	7226.0	56	12811
13	1992-93	9655.0	70	4095.0	30	13750
14	1993-94	13108.0	71	5308.0	29	18416
15	1994-95	15055.0	66	7601.0	34	22656
16	1995-96	2,0448.0	64	11329.0	36	31777
17	1996-97	24148.0	59	16645.0	41	40793
18	1997-98	29268.0	57	22148.0	43	51418
19	1998-99	31014.0	52	28704.0	48	59718
20	1999-00	37520.0	55	31000.0	45	68520

The export of bulk drugs went up from Rs. 3714.0 million 1990-91 to Rs. 37520.0 million in 1999-00 while export of formulations went up from Rs. 4134.0 million to Rs. 31000.0 million during same period (Table 6.3). The export performance of Indian pharmaceutical industry is particularly significant as it reflects the shift of the focus from the domestic market towards the global market.

Over the years the Indian government's policy regime used for regulating the pharmaceutical industry, has moved from strict government control in the 1970s to freeing it almost completely to allow market forces to guide it in the 1990s. The relative performance of the pharmaceutical industry in the industrial sector suggests the favourable impact of a mix of policies for the industry. However the signing of WTO agreements

especially TRIPS agreement will be affecting an important pillar of the Indian pharmaceutical industry's growth; The Patent Act, 1970.

The next section discusses the impact of the TRIPS on the Indian pharmaceutical industry structure and its strategic implications.

6.3 TRIPS and Indian pharmaceutical industry

The Indian Government signed the WTO trade agreements in 1995 and thus accepting to implement the TRIPS agreement as a framework to regulate the IPR management in the country. In 1999, the Government of India made its first amendment to the Patent Act as per the requirement of TRIPS, facilitating the introduction of a 'Mail Box' system and the Exclusive Marketing Rights (EMR) for products patented elsewhere. The mail box has initiated the process of accepting patent applications from January, 1995, which will be processed in 2005. In 2002 the Indian government announced the new Pharmaceutical Policy taking into account the new obligations undertaken by India under WTO agreement and resultant challenges faced by the Indian pharmaceutical industry. The Pharmaceutical Policy reduced the number of drugs under price control to 38 and introduced the Patents (Second Amendment) bill in Parliament providing patent protection for both products and processes and extending the life of a patent to 20 years.

During the negotiations on the WTO agreements, developing countries particularly India, China and Brazil were the strongest opponents of the TRIPS agreement. Till 1988 India and other countries prevented a major role for IPRs in WTO agreements but in 1989 India made a surprise move and gave up its opposition to include IPR in WTO negotiations. Ramanna (1999) suggests that while trade threats were important in initiating changes in global policy, domestic level policy change took place only with the mobilisations of a domestic industry and research institutes that favoured change. Trade pressure from the US through Special 301 was an important factor that influenced changes in Indian global policy. But importantly domestic policy shift also occurred and that enabled India to revise its patent laws in 1998-99. The change occurred at various levels. Economic liberalisation influenced perceptions of industry groups towards intellectual property laws. In tune with the pro-reform policy, important industry bodies in 1990s began to advocate the need for greater patent protection. The industry bodies began to support the bill to amend patent laws in conformity with the TRIPS agreement. According to an IPR consultant, Indian firms have realised that if you are part of trading network then you have to follow rules set by those agreements. He comments,

"if you are playing foot ball game and if you say I will kick everybody around the place, then rules don't allow you to kick around the place. You are allowed to push around within certain way, then you push around within certain rules".

A component of this change within industry bodies arose from some domestic firms who prospered under the existing patent structure, but came to visualise significant avenues for growth from the new patent regime. The NPIL strategic alliance director comments,

"I actually think it will be much better. The reason is simple as I think there will be greater awareness of IPR, there will be more scientists kind of working towards it and then rules also equal. Today we are in cowboy country, anybody copying anything, somebody have same product then they differentiate by adding some other combination which have no rational value and all kinds of things like that. I think that will stop and people who are genuinely have something innovative will be rewarded. So though most people think all the MNC have that ability, I don't agree with them, I think Indians also have that ability, to innovate and to make something new and to do very nice things".

This industry outlook was supported by the top Indian research and scientific institutes who felt that accumulated capabilities could provide benefit to them in the strong patent regime (Ramanna, 1999).

6.3.1 Impact of TRIPS on strategic orientation of Indian pharmaceutical industry

The basic tenet of the Indian Patent Act 1970 varies enormously from the framework established under the TRIPS agreement. Indian pharmaceutical firms which were manufacturing and marketing products without license from the original patented products will not be able to follow that course as part of their business strategy. The new patent law can not stop reverse engineering of drugs whose patents are expired but will certainly restrict its application in case of newly patented drugs. Now firms will need licenses from original patent holders to make those products. Even if firms are able to develop a patentable process for protected products, that process patent will be still dependent on the original product patent. As a result the Indian pharmaceutical industry and research institutes are now reviewing their strategies, policies and programmes to survive and succeed in the strong patent law regime. NPIL's head, Regulatory Affairs suggests,

"The main thing is after 2005, we will have product patent that is going to make main impact. It is not very clear how things are going to shape up. Different companies are looking at it differently".

Indian pharmaceutical firms are adapting multiple strategies like vertical integration, brand acquisition and marketing channel mix as a response to change in patent laws (Madanmohan and Krishnan, 2003). According to business development manager of National Chemical Laboratory,

"I see three developments; some companies will graduate to the new drug discovery, some will not do drug discovery in that sense but they will do drug delivery systems and that kind of innovations. There will be other group of firms who will be global scale generic producers and at least few of Indian firms will concentrate on supplying intermediate to all these firms".

The adoption of the TRIPs framework has forced Indian firms to focus on R&D and develop capabilities in different facets of pharmaceutical R&D. NCL's business development manager comments,

"With the globalisation and liberalisation there is focus on R&D today, industries realise this; today without R&D they can not survive. There is no option but to do R&D".

A few Indian pharmaceutical firms such as Ranbaxy and DRL are focusing on innovative R&D but at the same time seeking to garner a share of the global generics market. Some firms like Cipla are partnering with generics companies in the US for the supply of API and building capabilities for contract research. These firms are doing the contract process research and custom synthesis work for the western drug and generic companies. NPIL's R&D president comments,

"I am aware everybody cannot do NCE research to start with. The small group which concentrates on this kind of activity (custom synthesis and contract manufacturing) and get some money should be encouraged. This research involves designing of new processes for MNC pharmaceutical or generic companies to lower the cost of goods or developing new formulations to extend shelf or patent life".

The contract research model is similar to the Indian software firms' service model, where Indian IT firms are leveraging low costs and high skills to become the world's back office. But downsides of the contract service model like commoditisation of business which results in declining margins and an excessive dependence on their customers' fortunes are affecting the business models of Indian IT firms. In the pharmaceutical business, contract research and custom synthesis also have similar limitations. The NPIL R&D president suggests,

"Contract research has its own value, but anyone who is giving you a contract will attempt to save something for themselves. These activities will give you money but they can be never matched by NCEs. These activities become commodities very fast and can be given to your competitor setting up a shop next to you. Some degree of innovation is

involved in it but nothing to match NCE. At the end of the day most of us should focus on growth through hard core research and generating molecules".

The challenge facing the industry is to make a transition from an era of imitation based growth to innovation led growth. Lupin VP R&D comments,

"we are ready to sign TRIPS, what we need, then obviously innovation becomes the platform for growth; moving from the API to generic products and innovation either in area of new drug discovery or delivery".

R&D therefore has become an area of focus for Indian pharmaceutical firms and most Indian firms have increased R&D investments. The total R&D expenditure of the Indian pharmaceutical industry in 1965-66 was Rs.30 million but by 2000-01 it has reached Rs.37000 million (Table 6.4). Remarkably the average R&D intensity of top Indian pharmaceutical firms having a turnover of Rs. 5000 million and over has increased from 3.71 % in 2000 to 4.4% in 2002 (Pharmabiz, 2002).

Table 6.4 R&D expenditure of Indian pharmaceutical industry (Source: OPPI, 2001)

	Year	Rs. million
1	1993-94	12500
2	1994-95	14000
3	1995-96	16000
4	1996-97	18500
5	1997-98	22000
6	1998-99	26000
7	1999-00	32000
8	2000-01	37000

The transformation in large MNC pharmaceutical firms' R&D strategies has also brought new opportunities for Indian pharmaceutical firms. Globally the cost of the entire pharmaceutical R&D process has increased and fewer drugs have been discovered, forcing big MNC pharmaceutical firms' to re-examine the drug discovery process and strategies. Many MNC pharmaceutical firms are now collaborating with biotechnology firms as well as with small research intensive pharmaceutical firms as a source of new molecules. This collaborative approach is mutually beneficial as small firms get an opportunity to share the cost and leverage of technical capabilities. Indian pharmaceutical firms are also using these opportunities to compensate cost and capabilities gaps.

MNC pharmaceutical firms are also focusing on the narrow band of therapeutic life style diseases, hence vacating research space for small pharmaceutical firms. Some Indian

pharmaceutical firms are concentrating their innovative R&D efforts in those research spaces. According to Ranbaxy R&D president,

"in other words, today there are lots of disease categories available, say, in US $ 100 - 500 million range, which would be far below the radar of big pharmaceutical firms because the potential there isn't so high. But it makes perfect sense for Indian pharmaceutical firms to play there" (Business World, 2003).

Thus the Trade Related Intellectual Property Rights (TRIPS) agreement has forced Indian pharmaceutical firms to focus on R&D and develop innovative products to compete in the global market. Ranbaxy's corporate affairs VP summarises the change in the strategic orientation in Indian pharmaceutical industry,

"one thing became clear that once TRIPs has signed, you had window in which to have your own products. In generic market lifeline of an organisation is new products. In 2005 you will have product that will be recognised but process will become secondary. So therefore companies have to have pipelines and for that companies have to invest into new molecules development".

The next section presents the capability creation model to explain processes and stages involved in gradual movement of the Indian pharmaceutical industry from acquisition of basic minimum knowledge base towards the creation of new competence for innovation.

6.4 The capability creation model

The growth of the Indian pharmaceutical industry reflects the rise of the industry up the value chain in terms of activities involved in the pharmaceutical R&D. Lupin's VP R&D comments,

"if you see historically, from marketing to manufacturing, from R&D of API to generics and now we will be into drug discovery phase. It's a gradual up-gradation through which Indian pharmaceutical industry has gone through".

The growth of Indian pharmaceutical firms on the pharmaceutical value chain is closely aligned with various R&D learning processes. This section presents the capability creation model which discusses various learning processes involved in capability development and maps the upgrading of capabilities in the Indian pharmaceutical industry on the pharmaceutical value chain

6.4.1 Pharmaceutical R&D value chain

The pharmaceutical R&D value chain (Fig 6.1) characterises pharmaceutical R&D capabilities based on criterion of technological and marketing complexity against the margin of profit in market associated with a respective category. The intermediate bulk drugs are drugs in powder form and involve the lowest level of technological and marketing complexity and correspondingly have low levels of profitability, while new chemical entities result from highly technological complex research and require strong marketing infrastructure. Due to strong patent protection, the profitability associated with new chemical entities is very high as most of the time drugs have monopolist presence in markets.

In the value chain, technological complexities increase at each level with a corresponding increase in profit margin. The increasing technological complexity requires an increased input of original knowledge as well as stronger marketing and distribution infrastructure.

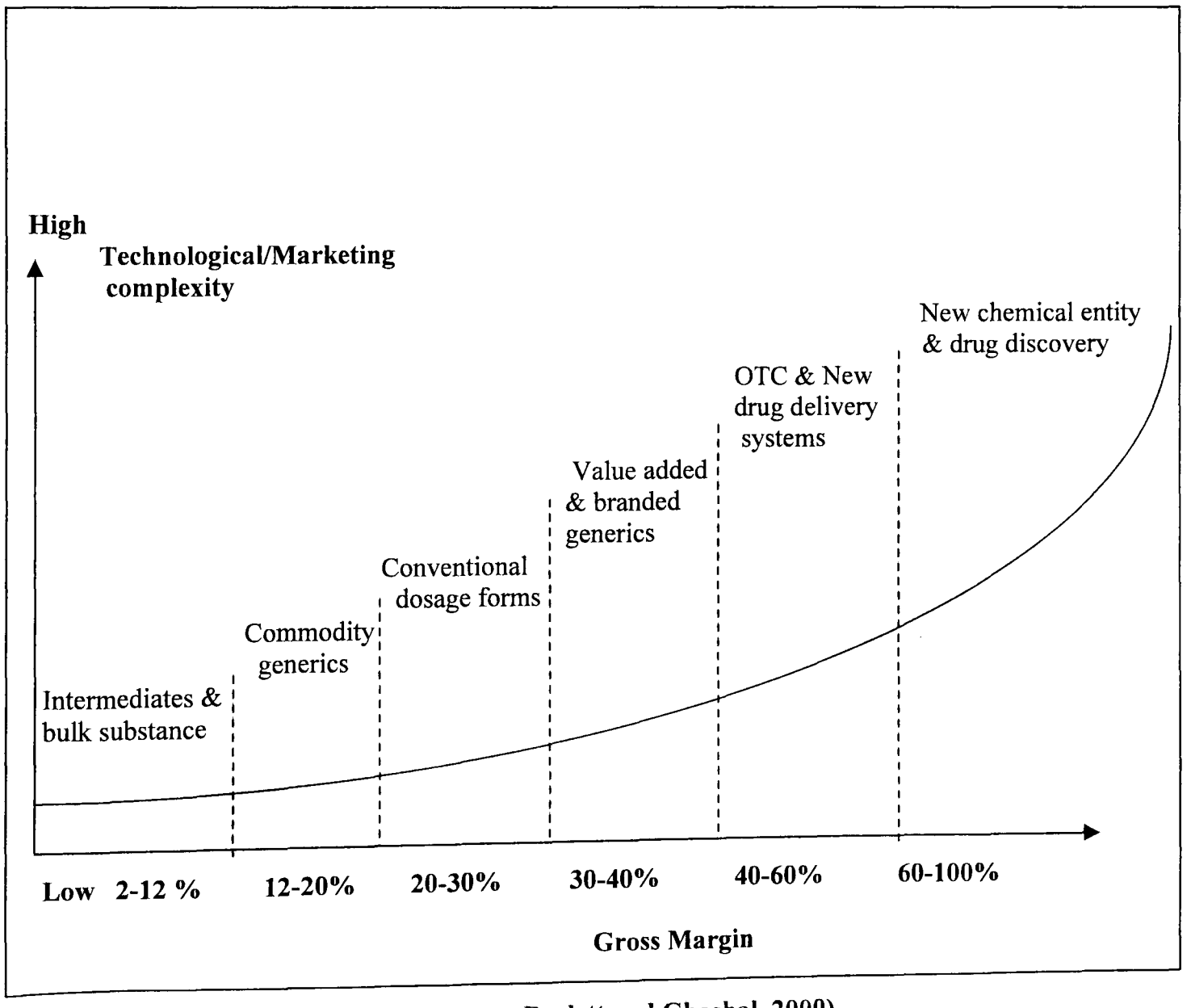


Fig 6.1 Pharmaceutical value chain (Source: Barlett and Ghoshal, 2000)

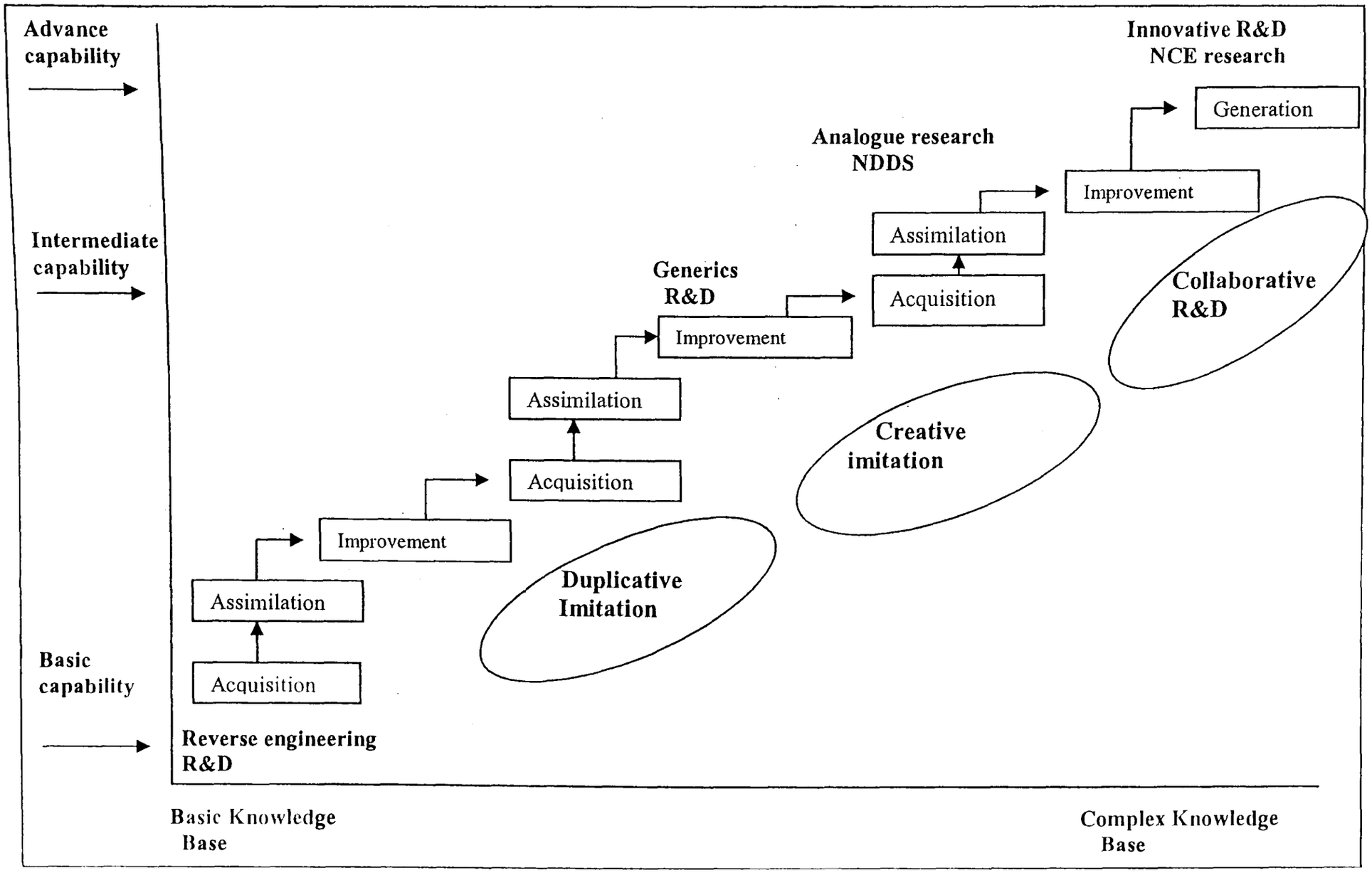
6.4.2 Processes involved in capability accumulation in Indian pharmaceutical industry

In the capability creation model (fig 6.2) a basic level of capability is taken as the ability to make minor adaptations to production and assimilate technology into a firm's environment. Intermediate innovative capability is the ability to generate incremental technical change in product design, quality and production processes, it also includes ability to search and evaluate external sources of technology. Advanced innovative capabilities refer to the ability to generate new products and process innovations. A knowledge base is categorised as simple and complex, based on the technological challenges involved in developing particular products and underlying capabilities. This classification of level of capabilities is based on Bell and Pavitt (1993) and Lall (1992).

Based on classification of capabilities in the pharmaceutical industry, reverse engineering R&D capability; ability to develop products by copying the process, is categorised as the basic capability. Generics R&D involves incremental change representing intermediate capability while new chemical entity research involves creating new drugs and innovative therapies representing advance capabilities.

Till 1970, most Indian pharmaceutical firms' initial forays into the pharmaceutical business involved marketing and distribution of imported pharmaceuticals. In 1960, close to 90% of market share was with MNCs and 10% with Indian companies. In the pre-independent era and up to World War II, Indian domestic production only accounted for a fraction of the market for medicine. There were less than 10 registered producers of Western-type pharmaceutical products in 1915 and 30 in 1947; many of them were producers of non-pharmaceutical chemicals. The Indian population was largely dependent on imports from foreign firms based in the UK, France and Germany for supply of medicines. The cost of these medicines was largely out of the reach for the majority of the Indian population (Felker et al., 1997). Therefore after independence, the Indian government focused on pharmaceuticals as a priority area and both, private and public investments were desired under the industry policy resolution. Several foreign multinational firms invested in India throughout the 1950s and 60s and until the 1970s these firms dominated the Indian market for pharmaceutical products. Some multinational companies only set up marketing and distribution facilities and imported bulk drugs from their manufacturing facilities. When the Indian government increased pressure against the import of finished products, MNCs set up formulation units and restricted imports to bulk drugs only.

Fig.6.2 Capability creation model



The Indian government set up research institutes in form of CSIR laboratories like Central Drug Research Institutes and invested in public sector enterprises to establish the domestic pharmaceutical industry. The first priority for the government was to become independent of imports as India was importing almost 90% of its bulk drugs requirement. Therefore in 1954, the Indian government set up a public sector pharmaceutical firm called Hindustan Antibiotics Limited (HAL) for the production of penicillin and sulfa drugs and in 1961 with the Russian cooperation Indian government set up another pharmaceutical firm; Indian Drugs and Pharmaceuticals Limited (IDPL). The public sector units along with the research institutes and MNC firms who started manufacturing in India developed the basic knowledge base required for the industry and emerged as main source of industrial entrepreneurs a decade later (Chaudhari,1999:11). The Pharmabiz editor comments on capability development in pre 1970 era,

"basically Indian firms like Sarabhai and Alembic were already here. Some of the scientists were working in these companies. Apart from that IDPL and HAL were there and so scientists were working in these two public sector companies. So scientists acquired skills over period of time through experiences".

Gradually Indian pharmaceutical firms started moving into the area of manufacturing formulations and followed it by backward integrating into production of bulk drugs. But 1970 patent law changed the industry structure and market by reducing entry barriers for entrepreneurs to operate in this science based industry. This law legalised reverse engineering R&D and paved the way for Indian firms to build basic capabilities in pharmaceutical R&D.

6.4.3 Duplicative imitation and basic R&D capabilities

In the post 1970 era Indian pharmaceutical firms focused on adapting technology to the firm and country specificity and efforts in these directions fostered the development of a basic knowledge base in firms. Indian pharmaceutical firms, taking the benefit of the weak patent law used reverse engineering or duplicative imitation as the main mechanism of knowledge acquisition and built basic capability in process R&D. National Chemical Laboratory's business development manager suggests,

"In early 1970 main driving force at that time was to make drugs available to Indian population. Products were known; only thing we have to develop was process either through reverse engineering or through process innovations. Since patent now protected process, we have to do reverse engineering and we developed alternative process. For last 40 years either research institute or industry did that, process development".

Managers working in public sector units, research institutes and other Indian firms sensed the opportunities that emerged after 1970 and started creating their own firms on the basis of knowledge in reverse engineering. According to a pharmaceutical consultant,

"the major factor was also people who were experienced in reverse engineering R&D moved from company to company and specially carried know-how with them".

Indian firms started developing drugs by copying or using known processes to manufacture the product at lower costs. Indian firms and research institutes simply followed the patent and reverse engineered the process, albeit with some minor modifications. Glenmark's strategic planning director comments,

"Earlier there was no R&D as such, it was simply reverse engineering; whatever patent said you would reproduce and optimise it".

Original product

A + B a' + C = original molecule

(Process conditions: temp: X; pressure: Y)

Reverse engineered product

A + b + d = Reverse Engineered Molecule where d = a'+c

(Process conditions: temp: X; pressure: Y)

Fig 6.3 Reverse Engineering Product Development

In reverse engineering (Fig 6.3), scientists study the different sequential steps involved in the making of the final compound. In some cases, scientists keep all these steps same and change the solvent or in some cases scientists change some steps and arrive at some product with a different process. In most Indian pharmaceutical firms, scientists developed skills in reverse engineering R&D through trial and error experimentation or learning by doing. The former R&D president of Ranbaxy explains the early efforts of firms,

"You have to train people; actually quite a bit of training has gone into this. Nothing like training, every body comes from university, and had no experience of reverse engineering. When there is no reverse engineering really per se in the universities as a course or anything so you have to teach them. Then there were few people already available they can train the younger one. So we have trained the people on the job, that itself investment for a year or so when they really start learning or giving results".

Reverse engineering R&D also involves purposive searching of the relevant information, effective interactions among technical members within a project team and with marketing and production departments within firm, effective interactions with suppliers, customers

and trial and error in developing a satisfactory result. Thus these activities helped Indian firms to develop basic capabilities in pharmaceutical product development and management.

Thus Indian pharmaceutical firms used imitative learning to develop basic capabilities in pharmaceutical R&D. Kim and Nelson (2000) suggest that the important aspect of imitative learning is to search for technological information and which is an important component of accumulating basic innovative capabilities. In the case of reverse engineering pharmaceutical R&D the publicly available knowledge in the patent is not always sufficient on its own to produce a reverse engineered product. Some knowledge is not disclosed in patents but importantly firms need to have the tacit knowledge to complement and interpret disclosed knowledge. Hence the non market imitative or reverse engineering based acquisition of knowledge is likely to require the firm to gain the necessary tacit knowledge and unavailable information, for example through trial and error. In the case of Indian pharmaceutical firms where new products were not registered by original patent holders in India, the Indian firms quickly compiled 'product dossiers' based on published data and supplemented them with limited Phase III clinical trials and got products approved by the drug regulatory authority.

The focus of Indian pharmaceutical firms in the context of reverse engineering R&D was not based on the number of patents firm has filed but on number of products firm could reverse engineer and duration for imitative process development. Indian firms competed in the fiercely competitive market; in the Indian domestic market there can be up to 100 brands for any one molecule. If an original patent holder has developed the product with process A, then other company develops the product with process B, third company tries to developed product with process C. In this process 6-10 companies are constantly developing new ways of manufacturing the product cheaply. The profitability of a drug in the market place was mostly determined by the cost and timing of entry in the market. According to a pharmaceutical consultant, pharmaceutical MNC's operate on 95% production margins; total cost of manufacturing involved in the development of the drug is 5%. So the marginal or significant improvement in process development does not have a significant effect on profit margins. The Indian pharmaceutical firm operates on an 8% production margin; the cost of manufacturing makes up the 92% of total cost of the product. Therefore even if a firm does a .5% improvement in process, then firm can achieve a significant improvement in margins which finally can result in an effective increase in profit. This was the driving force for firms in developing efficient cheap processes as .5% on an 8% margin makes a big difference. Thus the profits in the market were directly related to the efficient production processes used by firms and so Indian

pharmaceutical firms put an intensive in house effort to develop cheap processes. This resulted in the rapid acquisition and assimilation of reverse engineering expertise across all firms. Although, this also resulted in the lack of collaborations between industry and academia, as profits were totally linked to the superior production process, firms' made an effort to build these capabilities in-house. Along with that lack of trust due to a weak regularity environment, hampered the development of collaborative research networks between the industry and academia.

Kim and Nelson, (2000) point out that a reverse engineering strategy also involves activities that senses potential needs in a market, activities that locate knowledge or products, which would meet the market needs, and activities that would infuse these two elements into a new project. As a result of these activities Indian pharmaceutical firms built organisational capabilities required to operate scale intensive manufacturing facilities, production as well as created strong marketing and distribution networks domestically.

By the end of 80s, Indian firms were practically manufacturing every new molecule which was commercially viable to manufacture without access to process details from the innovator company.

Table 6.5 Time lag between introduction of new drug in the world market and its introduction in India (Source: Keayla, 1996)

No.	Drug	World market introduction by inventor	Indian market introduction by domestic firm	Time lag before introduction in India (years)
1	Ibuprofen	1967	1973	6
2	Salbutamol	1973	1977	4
3	Mebendazole	1974	1978	4
4	Rifampicin	1974	1980	6
5	Cimetidine	1976	1981	5
6	Naproxen	1978	1982	4
7	Bromhexin	1976	1982	6
8	Captopril	1981	1985	4
9	Ranitidine	1981	1985	4
10	Norfloxacin	1984	1988	4
11	Ciprofloxacin	1986	1989	3
12	Acyclovix	1985	1988	3
13	Astemizole	1986	1988	2
14	Larazepam	1977	1978	1

One of the indicators of Indian firms' superior imitative capabilities is the shortening of the time lag between the introduction of a drug in the global market by the inventor and the marketing of the same drug in the Indian market. Over the years Indian firms have been able to progressively shorten the lag between introduction of a drug by inventor and its introduction in the Indian market indicating superior process R&D capabilities (Table 6.5).

6.4.4 Creative imitation and intermediate R&D capabilities

After the liberalisation of the pharmaceutical market in the mid 1990`s, some Indian pharmaceutical firms moved towards export markets and specifically generic markets in advanced countries. Indian pharmaceutical firms adopted the strategy of 'creative imitation' to manufacture products by developing non-infringement processes. These non-infringing processes can be converted into a patent, which creates a value for firms in the market. According to Kim and Nelson (2000) design copies, creative adaptations, technological leapfrogging and adaptation to another industry are different forms of creative imitations. Creative adaptations are innovative in a way that they are inspired by existing products but differed from them. Creative imitations are aimed at generating facsimile products but with a new performance features. It not only involves activities like benchmarking but also notable learning through substantial investment in R&D activities to create imitative products, which may have significantly better performance features than the original.

Using reverse engineering R&D, Indian pharmaceutical firms built capabilities in process development and by late 1980s these firms could produce several block-buster drugs in formulation as well as bulk drug forms at considerably lower costs. In the post 1990 era, Indian firms started developing processes which contained some patentable novel element. The Ranbaxy Vice President of corporate affairs argues,

"what happening was more innovative way of producing the drug; if you would look at what Pfizer did, what DRL did and what Ranbaxy did for various products. Example, Prozak which is Fluoxentine used to be sold in particular dosages and strengths. DRL not only developed the new process to make Fluoxentine but also they developed new dosage form and therefore they got exclusivity in the US. So that innovation".

The success in generic R&D involves strong interaction and coordination between IPR, marketing and R&D departments and therefore requires presence of organisational mechanisms to facilitate these interactions. The creative imitation process starts with the

top management of company selecting a molecule to be developed based on criteria's like patent expiry date, market value and complexity of the molecule. Then regulatory team scouts use the patent database to search and study for loopholes in patents related to selected drugs and report to the R&D team all key information about existing patents on the product, for example, different process patent filed by originator. This is crucial step in designing the non-infringing and novel process. Then R&D team studies all possible patents –for hydrides, polymorphs, isomers, other crystalline forms and metabolites. The main task of R&D team is to find the process that don't infringe on any of the originator's process patents. The R&D team has to chemically produce a compound in an efficient way with the same level of bioequivalence as the original compound. Once the R&D team develops the non-infringing process, the regulatory and legal team joins the project again. These teams start working on filling the regulatory approval in terms of a drug master file (DMF) in case of bulk drugs or abbreviated new drug application (ANDA) in case of formulation products for the US and European markets. The product then moves to the firm's pilot plant for validation and production of exhibit batches to be submitted to the FDA with the drug master file or ANDA application.

A Drug Master File (DMF) is a submission to the Food and Drug Administration (FDA) containing confidential, detailed information about facilities, processes or articles employed in the manufacturing, processing, packaging, and storing of one or more drugs intended for use in humans or animals, while abbreviated new drug application contains data which when submitted to FDA provides for the review and ultimate approval of a generic drug product.

Generic drug applications are termed "abbreviated" because they are generally not required to include preclinical (animal) and clinical (human) data to establish safety and effectiveness. Instead, generic applicants must scientifically demonstrate that their product is bioequivalent (i.e., performs in the same manner as the innovator drug).

Lupin's IPR head explains the subtle difficulties involved in imitating the process creatively,

"suppose you have new molecule and you will like to protect this molecule as far as possible and so you would like to surround it with as many patents as possible. Every major pharmaceutical firm is doing it. Now if I have to enter generic phase after the patent expiration, I have to ensure that I do not fall within spaces covered by the patent of those companies to avoid all that litigation and all that things. So I would have to

develop the process of formulation or new product which is beyond the boundaries whatever covered by the scope of the patent. So I would not infringe upon rights of others. This was not done 5-6 years ago, but this is done now. All Indian pharmaceutical firms are focusing on generic markets. Firms want to make sure that it is not going to be sued for infringement. That's role of R&D; it ensures whatever product we develop, it does not infringe on patent of others".

The important aspect of imitation in generics R&D is to copy the product with innovative processes. Thus Indian firms acquired their generics R&D capabilities by assimilating and creatively improving on their reverse engineering R&D capabilities. This creative imitation allowed Indian pharmaceutical firms to develop the regulatory capability required to access global markets, build organisational structures required to manage original research and gain entry into the generic markets of advanced countries. Thus, Indian pharmaceutical firms moved up the pharmaceutical R&D value chain by developing products for highly regulated generics markets in advanced countries.

Indian pharmaceutical firms initially exported formulation products to least developed or developing countries but after 1990 these firms started exporting formulations products to generics markets in advanced countries. An important event in the expansion of a generic market in the US was the enactment of the Waxman-Hatch Act in 1984. This abolished the requirement of fresh clinical trials in case of generic drugs and replaced them with the simpler and less expensive 'bioequivalence' and 'bio-availability tests'. There are two ways to approach the US generics market; a. Para III – in which case fillings are mainly driven by patent expiry and b. Para IV which signifies the patent challenge route to create and tap a block buster opportunity by gaining an exclusive marketing right for a limited period of time. Some firms like DRL are aggressively pursuing the Para IV route of patent challenge, which is a high risk, high return strategy where firms apply for patent challenging validation of existing patents and by that, taking on an original patent holder. Others like Sun Pharmaceutical and Ranbaxy have followed the conservative approach of Para III filling. Some firms like the Cipla are looking at ways to grow in that space through tie ups, alliances, etc. with other generic firms like Watson and Ivax.

Table 6.6 Share of bulk drugs and formulations in total exports (Source: OPPI, 2001)

No.	Years	Bulk Drugs (%)	Formulations (%)
1	1990-91	47	53
2	1991-92	44	56
3	1992-93	70	30
4	1993-94	71	29
5	1994-95	66	34
6	1995-96	64	36
7	1996-97	59	41
8	1997-98	57	43
9	1998-99	52	48
10	1999-00	55	45

Indian pharmaceutical companies have adopted different kinds of strategies to enter the US generic markets. Many Indian pharmaceutical firms have set up their marketing infrastructure in the US. Some firms have acquired US based firms to set up an operation while other firms are forming alliances with generic firms operating in the US for the supply of API or formulation generic products (Table 6.7).

Table 6.7 Foreign acquisitions by Indian pharmaceutical companies (Source: Annual Report, 1995-2003)

No.	Year	Indian firm (acquirer)	Name of the firm acquired	Country
1	1995	Ranbaxy	Ohm Labs	USA
2	1997	Sun Pharmaceuticals Ltd	Caraco	USA
3	1998	Wockhardt	Wallis	UK
4	2000	Ranbaxy	Basics	Germany
5	2000	Ranabxy	Veratide	Germany
6	2002	Ranbaxy	Signature	USA
7	2002	Unichem	Niche Generics	UK
8	2002	Dr. Reddy's Laboratories	BMS	UK
9	2002	Dr. Reddy's Laboratories	Meridian	UK
10	2003	Wockhardt	CP Pharma	UK
11	2003	Zydus Cadila	Alpharma	France
12	2004	Ranbaxy	REG Aventis	France
13	2004	Glenmark	Lab Killinger	Brazil
14	2004	Dr. Reddy's Laboratories	Trigenesis	US
15	2004	Jubilant Organosys	PSI group	Belgium

In the post 1990 era Indian pharmaceutical firms invested heavily in improving production facilities and adopted Good Manufacturing Practices (GMP) and now most of the leading companies have their manufacturing facilities approved by the USFDA and UK's MCA. By 2003 India had highest number of FDA-approved plants outside the US. India's 61 such plants are closely seconded by Italy's 60 plants (Fig. 6.4).

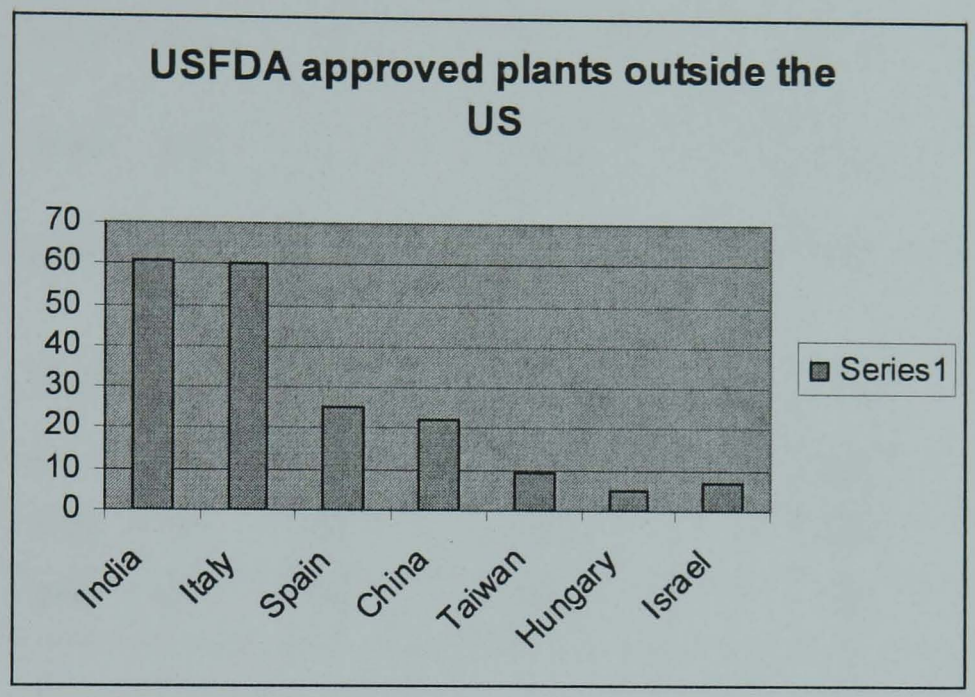


Fig 6.4 USFDA approved plant outside US (Source: US FDA)

Indian pharmaceutical firms filed patents for the indigenously developed novel and non-fringing processes with the regulatory authorities in the Europe and US. In earlier years filling patents in different regions, which required the same amount of data as regulators from the developed world helped these firms in acquiring the minimum regulatory expertise. This proved to be an effective mechanism for gathering the knowledge required for the successful filing of patents in the US and Europe. The experience was further strengthened by the successful filing of patent applications for generics (ANDA) in the US and by 2000 Indian pharmaceutical firms had firmly established generics R&D capabilities and associated regulatory capabilities (Table 6.8). There has been a spate of DMF fillings from 2000 and now even small firms are getting into the value added ANDA segment. In 2003 Indian pharmaceutical firms filed 73 ANDA applications with US FDA constituting 20% of the total fillings. At the end of 2003 Indian firms had a total of 106 ANDAs approved by the FDA while 108 more ANDAs are filed but yet to get approvals. In 2003 Indian firms submitted 119 DMFs accounting almost 30% of total submissions DMF submissions in USFDA.

Table 6.8 Share of Indian firms in ANDA approvals and DMF submissions to USFDA (Source: US FDA)

Year	ANDA			DMF		
	Total	ANDA by Indian firms	Share of Indian approvals	Total	DMF by Indian firms	Share of Indian submissions
1997	572	10	1.7	371	31	9.7
1998	484	9	1.9	944	38	4.0
1999	380	8	2.1	390	44	11.3
2000	583	21	3.6	355	37	10.4
2001	436	18	4.1	344	59	17.2
2002	753	32	4.2	368	79	21.5
2003	627	56	8.9	426	119	28.2

The exposure to global markets, realisation of future regulatory changes and creative orientation to imitative research, all facilitated the development of the 'research tradition' in these firms. Nelson and Winter (1982) reflecting on the imitative learning suggest that 'an imitator working with an extremely sparse set of clues about the product might well adopt the more prestigious title of 'innovator', since most of the problem is really being solved independently'. This upward movement of Indian firms represents the intermediate capability stage as the products resulting from generic R&D require input of original knowledge and can give leverage to firms in global markets.

In the case of Indian pharmaceutical firms the creative imitation in the form of generics R&D accelerated their movement towards the acquisitions of advanced level capabilities further up the value chain in pharmaceutical R&D.

6.4.5 Collaborative R&D and advance R&D capabilities

The movement from intermediate R&D capabilities to advanced R&D capabilities is very challenging due to the difference of knowledge base and organisational capability. However, the creative imitation in the form of generics R&D has increased Indian pharmaceutical firms' awareness of opportunities in new drug delivery systems (NDDS) and NCE research. Many skills and activities required in generic R&D are applicable in the innovative process R&D. The managerial experience in generics R&D has given Indian firms some understanding of the complexities involved in innovative research and

organisational infrastructure associated with it. Due to their generic business, these firms have built information channels with scientific community in advanced countries.

The advance level of technological capabilities in the case of pharmaceutical R&D involves new chemical entity research either by using research strategies like analogue research or rational drug design and in terms of process R&D, new drug delivery systems.

Analogue research involves working on predetermined targets for specific diseases to develop molecules that alter the target's mechanism in the diseased person while rational or structure based drug design involves the determination of a disease causing protein's three-dimensional structure. Once the structure is known, novel chemical entities are designed to 'lock-in' to the protein with the aim of reversing or arresting a disease's progression.

The main focus in drug delivery system research is in improving the effectiveness of an existing drug, in terms of dosage, length of treatment and biodegradability. Many Indian pharmaceutical firms with a proven track record in process R&D see new drug delivery systems as a risk free strategy. The drug delivery improvements do not impinge on the product patents and the cost of stage I and II trials for an improved drug cost almost 1/10 of a new drug. An improved version of an existing drug also assures good market success.

From 1995, the large Indian firms started investing heavily in new drug discovery research and new drug delivery system research as a response to emerging post TRIPs scenario. Lupin's Vice President of R&D suggests,

"Firms have decided strategically whether they should go into drug discovery or drug delivery systems. Some companies like DRL clearly gone into drug discovery and then companies like Ranbaxy who first gone into drug delivery and then drug discovery. It is doing both. So you see again over a period of time; innovation being the platform, R&D becomes the key".

In terms of new chemical entity research, Indian pharmaceutical firms' strategy is not to compete with multinational giants like Pfizer or Glaxo, instead their strategy is to leverage technical skills. These firms have filed patents for innovative products by using an analogue research as their main research strategy (table 6.9). Indian pharmaceutical firms are working with already validated or known targets where structural activity of the compound is well known and these firms try to find a compound that possesses a better efficacy or fewer side effects.

Table 6.9 Indian pharmaceutical firms' new chemical entity pipeline (Source: Annual Report, 2003)

No.	Companies	Molecules in clinical trials
1	Ranbaxy	6
2	DRL	4
3	NPIL	1
4	Lupin	2
5	Dabur	2
6	Wockhardt	1
7	Torrent	2
8	Glenmark	1
9	Sun Pharma	2
10	Orchid	1

In the beginning, Indian firms faced major constraints such as financial and infrastructural resources, an insular knowledge base and lack of scientists trained in innovative R&D. To leverage the financial cost, Indian pharmaceutical firms started investing the revenue generated from generic business into innovative R&D. The other strategy used by Indian pharmaceutical firms to cover the financial cost was to partner with MNC pharmaceutical firms through licensing of molecules or drug delivery system technology. These licensing agreements usually involve milestone payments and limited marketing rights. An Indian pharmaceutical consultant describes the early efforts of these firms,

"These companies saw the writing on the wall and worked towards developing the expertise in new areas of drug discovery and development research, considering the low resources available to them in comparison to those of MNCs, they have adopted a strategy of collaborative research through a licensing route, by gaining up-front milestone and royalty payments for the molecules licensed by them to MNCs for further clinical development".

For example, Torrent pharmaceutical licensed its anti diabetic molecule to Novartis at a preclinical stage. According to the agreement, initially Torrent will receive a payment of USD 0.5 million and it will develop the molecule till a predefined stage. At this stage Novartis will have the option to acquire rights for further development. If Novartis exercises this option then Torrent will receive an initial payment of $3million and subsequent milestone payments depending on progress. If the product is commercialised Torrent will get royalties and will also lead the co-promotion of the product in India.

The low cost of research in India has also helped Indian pharmaceutical firms' to overcome financial constraints associated with new drug discovery. The cost of drug discovery and development in India could be one tenth of the cost involved in the development of a new molecule in advanced countries. The NPIL strategic alliance director comments,

"I think luckily for us infrastructure cost is not that much. You can buy machines made in Indian industries; they are very good. Let's say you want to increase your chemical lab from 1 to 4 how much you will spend on utilities, how much you will spend on gases or air conditioning or chilled water etc. The cost per dollar per scientist is much less here than in the US. See you can replicate that, so infrastructure doesn't cost that much here. Therefore there for US$ 50 million you will hardly get 2 rooms; here you can get the whole factory, its same thing".

The other major constraint faced by Indian pharmaceutical firms was the knowledge gaps in the new chemical entity research, especially in various disciplinary areas involved in drug discovery. Indian pharmaceutical firms filled the knowledge gaps by hiring Indian scientists experienced in drug discovery R&D and adopting a strategy of collaborative research with Indian as well overseas research institutes. In the post 1995 era R&D scientists became the focus area in the Indian pharmaceutical industry as Indian firms hired scientists from India as well as overseas universities, companies and research institutes. Ranbaxy's Vice President, corporate affairs explains,

"Indian firm did three things; first they recruited people who had that experience. So you have Dr. Venkatswarlu in DRL and you have Dr. Khanna in Ranbaxy and host of other people; it's not just one person. Second it started doing recruitment in university campuses overseas, in areas where educational qualifications were not available in India and lastly it stared sending scientists to symposia, training programmes, conferences to pick up the ideas".

The new drug discovery research requires knowledge about various disciplinary areas and effective knowledge transfer mechanisms to facilitate the flow of knowledge. Indian pharmaceutical firms employed a collaborative R&D approach to tap disciplinary knowledge bases in research institutes. The NCL director points out,

"we have strong group in peptide and nucleotide chemistry and you see lot of interest from industry. Although 10 years ago we had same people with same group and nobody was interested, now we have lot of work".

Indian research institutes have built a strong supporting infrastructure as required in drug discovery R&D such as analytical instruments and facilities for research which most firms in the industry are still lacking. For example, the National Chemical Laboratory have the combinatorial chemistry machine while the Central Drug Research Institute owns a high through-put screening machine. According to NPIL's R&D president,

"Putting up a modern drug discovery structure may not be possible at present since it would need an ultra high throughput screening and big combinatorial chemistry, or a big genomic research or molecular modelling. It may be nice to get into this, but it is too much money for Indian companies".

Indian pharmaceutical firms are collaborating with Indian research institutes to use these supportive infrastructural facilities. NPIL's head of regulatory affairs comments,

"now a days government funding to research institutes has gone up a lot, I would say compare to old days these institutes are really very well of. In fact they have more modern instruments than industry, in old days it was reverse. So may be you can have tie up like some of them have facilities for generating combi-chem libraries, high throughput screening facilities and all these kinds of things. So in fact CSIR allows a firm to use laboratories facilities and share the IPR".

Recognising the imperativeness of taking proactive measures to give the necessary fillip to R&D, the Government had set up various schemes to encourage collaboration between research institutes and industry. In 1995 under the Department of Science and Technology, the Indian government launched a programme called the New Millennium Leadership Technology Initiative (NMLTI) to bring industry and academia together. The basic objective of this initiative is to synergise the facilities and competencies of publicly funded R&D institutions, academia and private industry for developing technologies for the Indian industry. The NMLTI programme caters to all industries and is not restricted to the pharmaceutical research only. With a financial outlay of Rs. 800 million, DST has sanctioned 49 pharmaceutical industry/institutions collaborations so far. In this programme 50% funding comes from the government and 50% from industry.

The Indian government also took major initiatives to increase the interactions between industry and public R&D institutions in areas of innovative pharmaceutical R&D. In 2000, the Indian government created a Pharmaceutical Research & Development Support Fund (PRDSF) with an allocation of Rs.1500 million to start with as a plan fund for promotion of R&D in the pharmaceutical Industry. Recently the Department of Science and Technology cleared five industry- institution research proposals to be funded through the PRDSF programme.

Due to these initiatives many research laboratories have taken up industry sponsored research and established strong partnerships with industrial firms on a long term basis for product and process development projects. A patent consultant comments,

"Department of Science and Technology (DST) has come in big ways and supported a lot with funds; if you see the allocation they are almost doubling over the years. So the scientists which are trained in the CSIR institutes are being given considerable exposure to the international R&D. These scientists are sent for internship and for short term research in institutions abroad. CSIR labs are also initiating lot of exchange programmes and scientists coming from abroad".

In the post TRIPs era CSIR had launched many initiatives as a response to the changing needs of the industry and knowledge generation. According to NCL's business development manager,

"in case of national laboratories, we have integrated programme of 90 laboratories and we are looking at leads from plants. We also have industry supported programme under the department of science and technology, we are working together with the industry".

The research institutes redefined their role for a post TRIPS scenario by investing in development of expertise in drug discovery research, generics research and building different relationships for each expertise. In the past, academic research meant just publishing journal papers but not releasing technologies into the market place. But now CSIR labs are becoming more market oriented and collaborating with industry to bring the inventions into the market place. Lupin's Vice President R&D suggests,

"academic institution culture is also changing in line with 2005. Today publication is not the measure, patent is measure, innovation is measure. So most academic institutes are working on innovative research. Most academic institutes are trying to collaborate with the industry. Industry is also trying to outsource some work to academia. To get to see what innovation is there, we collaborate together. So there is a lot of cooperation going on between industry and academia and systems, disciplines are in place. Pharmaceutical heads are in monitoring committee. It has to have commercial viability; it must have ownership by industry for whatever academia is doing so that automatically set the focus. Some accountability has to be there, some deliverables, measurable, timeframes and cost".

Thus Indian pharmaceutical firms are developing advanced pharmaceutical R&D capabilities by adopting collaborative research strategies.

6.4.6 Capability creation model: Summary

The capability creation model provides a broad sketch of activities, depths of knowledge and abilities associated with the Indian pharmaceutical industry's rise up the value chain. The capability creation model reveals that the Indian pharmaceutical industry moved from basic R&D capabilities to advanced level R&D capabilities by undertaking different types of activities involving R&D processes like duplicative imitation, creative imitation and collaborative R&D.

Over the years the Indian pharmaceutical industry has emerged as one of the most technologically advanced knowledge based industries in developing countries. Indian policy makers used patent law to infuse life into domestic pharmaceutical firms and provided these firms with protection from competition. Indian firms developed capabilities for producing drugs in bulk and formulation form by using duplicative imitation. In the beginning of 1990 the Indian government liberalised the economy and along with that also opened the Indian pharmaceutical market to multinational firms. Indian pharmaceutical firms responded to this challenge by flooding the generics market in advanced countries with drugs developed through creative imitation. The duplicative imitation era gave these firms two advantages that facilitated generics R&D capability creation –

a. cheap and scale intensive manufacturing facilities and

b. world class organic chemistry skills, honed by years of reverse engineering.

However with the strengthening of patent law, Indian firms focused on creating a business around intellectual property (IP) products by conducting drug discovery research. These firms used collaborative R&D approaches to develop advanced capabilities in pharmaceutical R&D while funding these investments through formulations and bulk generics business.

6.5 Conclusion

This chapter described Indian industrial and technological policies and reviewed its impact on the development of the Indian industrial technological capability. The review suggests that the pharmaceutical policies adopted by the Indian government played a key role in growth of Indian pharmaceutical firms. The different Indian policy regimes influenced firm level learning processes and shaped the technological capability accumulation in the Indian pharmaceutical industry. The capability creation model showed different learning processes like duplicative imitation, creative imitation and collaborative R&D used by Indian pharmaceutical firms to move from basic capabilities to advanced capabilities, reflecting the impact of different policy regimes. The implementation of the TRIPS agreement represents an important change in the Indian government's pharmaceutical

policy in terms of IPR management in country. The analysis suggests that TRIPS has increased focus on R&D in Indian pharmaceutical firms and accelerated the movement of Indian pharmaceutical firms towards the development of innovative R&D capabilities.

The next chapter presents the case of six innovative Indian pharmaceutical firms and discusses the development of capabilities in each firm.

Chapter 7

INNOVATIVE INDIAN PHARMACEUTICAL FIRMS

7.1 Introduction

This chapter describes the development of innovative organisational capabilities in six Indian pharmaceutical firms; Ranbaxy laboratories, Dr. Reddy's Laboratories, Wockhardt, Nicholas – Piramal ltd, Lupin Laboratories and Glenmark pharmaceuticals ltd. The focus of the description is on the processes associated with the transformation of capabilities from imitative R&D to innovative R&D in each firm. These firms are used as case studies in this research and therefore the findings of this research are based on the analysis of these six cases.

Ranbaxy and Dr. Reddy's Laboratories started investing in innovative R&D from the early 90s while Wockhardt and Nicholas Piramal started in the late 1990s. Lupin and Glenmark entered the innovative R&D programmes later than the other firms in this study.

Table: 7.1 Firms under investigation

No.	Name of the firm	Status	Year of establishment	Year of starting Innovative R&D	Focus Area	Turnover 2003-04 Rs. Million
1	Ranbaxy laboratories ltd	Indian MNC Innovative leader	1962	1992	Generics NDDS NCE	45,301
2	Dr. Reddy's laboratories ltd	Innovative leader	1984	1994	Speciality generics NCE	20,081
3	Wockhardt	Innovative Follower	1959	1997	Biotech drugs NCE	7,671
4	Nicholas Piramal (I) ltd	Innovative Follower	1988	1998	Contract research NCE	12,690
5	Lupin Laboratories Ltd	Innovative Beginner	1968	2001	Herbals Generics NDDS/NCE	12,327
6	Glenmark Pharmaceuticals Ltd	Innovative Beginner	1977	2000	Generics NCE	3,806

7.2 Ranbaxy laboratories

Ranbaxy Laboratories Limited, India's largest pharmaceutical firm, is ranked amongst the top ten generic companies in the world. It manufactures and markets branded generic pharmaceuticals, non branded generic pharmaceuticals and active pharmaceutical ingredients (API) across the world.

Ranbaxy traces its roots to 1962, when Bhai Mohan Singh's family entered into a collaborative agreement with the Italian pharmaceutical firm Lepetit SpA for the manufacture of the typhoid drug 'Chloramphenicol' in India. In 1967 a change in Lepetit's strategy prompted the family to buy them out. In 1973, Ranbaxy became a public limited company and began a major investment programme that included construction of a large manufacturing plant, initially aimed at producing active pharmaceutical ingredient for the Hoffman La Roche tranquiliser, Diazepam. Like other Indian pharmaceutical firms, Ranbaxy's early focus was chemical synthesis, or reverse engineering, of known compounds. Ranbaxy rapidly developed a strong expertise in process R&D and prepared several dosage formulations of the drugs with cheap alternative processes. Soon Ranbaxy began exporting active pharmaceutical ingredients and dosage forms on the basis of this formidable capability in reverse engineering. From the early 1980s Ranbaxy's started concentrating on the international markets for active pharmaceutical ingredients and gradually secured an entry into these markets. In 1978 Ranbaxy entered its first international market, Nigeria, through a joint venture and in 1984 Ranbaxy expanded its operation to Malaysia. According to Ranbaxy' MD, operating in the open and very competitive Malaysian market tested and shaped Ranbaxy's capabilities for future international expansion (Brar, 2004). The Malaysian operation helped Ranbaxy in learning to compete in free markets and enabled the company to build competencies in highly regulated generic markets in advanced countries.

Dr. Parvinder Singh, the chairman and CEO of Ranbaxy from 1993 until 1999 played a key role in shaping Ranbaxy's long term vision. In 1993 taking note of the possible strategic effect of the TRIPS agreement on the Indian regulatory system, he articulated the new mission for the company: to become 'a research based international pharmaceutical company with $1billion in sales by 2003'. The mission statement took into account the changing dynamics of the domestic pharmaceutical market as a result of the product patent regime that will exist by 2005, prompting the company to start investing in R&D to develop its own molecules. This prompted Ranbaxy's globalisation strategy with the company's top management setting up a mission to move from a turnover of $ 300 million in 1993 to US$1 billion in 10 years. Ranbaxy employed a range of strategies, including alliances, partnerships and acquisitions to gain the flexibility needed for viable and

profitable business operations worldwide. Ranbaxy's major focus was on the generic market in advanced countries and to cater to those markets the company began developing indigenous innovative production processes for drugs.

7.2.1 The generics strategy

Based on the globalisation strategy Ranbaxy entered the US market in 1995. In 1996, Ranbaxy acquired a New Jersey based firm called Ohm Labs and started a joint venture with Schein pharmaceuticals for marketing Ranitidine in US. Such agreements helped Ranbaxy in establishing manufacturing operations in the US and allowed the company an entry into US generic markets. More importantly, Ranbaxy started applying for patents all over the world for innovative production processes developed indigenously by the company's R&D teams. This enabled Ranbaxy to market almost a third of its major products internationally and maintain a steady increase in its net foreign exchange earnings throughout 1990s. The experienced gain through such practise also developed the company's regulatory skills needed to obtain approvals for its products under the Abbreviated New Drug Applications (ANDAs) scheme in the US. Since 1995, it has filed for 127 ANDA and has received 81 approvals; the highest for an Indian company (see Table 7.2)

In 1998 Ranbaxy established a 100 percent subsidiary in the US called Ranbaxy pharmaceuticals Inc and started marketing products under its brand name. Within just four years of starting its US operations, Ranbaxy touched the US $ 100 million mark in the US. This proved to be an important turning point in company's growth. By 2003, Ranbaxy reached a position among the top 10 biggest players in US generic market.

Table 7.2 Ranbaxy's generic product filings (Source: Annual Report, 2003)

Year	DMF (Drug Master Files)	ANDA
Till 1999	16	49
2000	6	12
2001	8	15
2002	7	25
2003	9	26
Total	44	127

Along side the US market, Ranbaxy began spreading its operations in Europe. In 1995 it set up a manufacturing plant in Ireland and opened a subsidiary in the UK. This proved instrumental in Ranbaxy's forays into other European markets. In 2004 Ranbaxy acquired

RPG Aventis SA, the fifth largest generics company in France. RPG has a market share of 6% in France which is the fourth largest pharmaceutical market.

The success of Ranabxy's globalisation strategy is reflected in the expansion of its world wide. The company's products are now sold in more than 100 countries, have manufacturing operations in 7 countries and a ground presence in 34 countries. In 2003, Ranabxy achieved annual turnover of Rs. 45,301 million (US$ 972 million) and registered robust growth of 27%. Overseas markets contributed 76% of total turnover, out of which advanced markets like USA/ Europe accounted for more than 50%.

Table 7.3 Globalisation of Ranbaxy's business and subsequent transformation in markets, products and capabilities (stars indicate importance/direction in the segment) (Source: Brar, 2001)

	1980-89	1990-99	2000 - beyond
Strategy			
India	* * *	* * *	
Exports	* *	* * *	
International		* *	* * *
Market			
Developing	* *	* *	*
Emerging	* * *	* * *	* * *
Advanced		* *	* * *
Products	**API,** Dosage forms	**Generics,** Branded generics	**Proprietary** technology Platforms, NDDS, VGS
Competencies	**Backward Integration**	**Developmental research, regulatory Manufacturing, Marketing**	**Innovative research, patents, Legal brand marketing for Rx products**

The globalisation strategy allowed Ranbaxy an opportunity to learn about competitive practices required to succeed in intermediate markets. Table 7.3 shows the transformation in Ranbaxy's strategic orientation in terms of strategic markets, products and competencies. The globalisation of business has helped Ranbaxy in deriving benefits of

economies of scope and scale in larger markets, facilitated the expansion and diversification of its product portfolio and aided development of competencies in innovative research and regularity areas. In 2004 Ranbaxy passed the turnover of US$1 billion and evolved a new mission till 2012 for sustaining significant growth called 'Vision Garuda', which involves the transformation of the company into a $5-billion company by 2012. By then, Ranbaxy hopes to place its own drugs in the market and have a healthy pipeline of new drugs under development.

7.2.2 Research and Development

Ranbaxy laboratory's initial forays into research and development activities began in the late 1970s. According to its former R&D president, until 1979 there was no research to speak of and the R&D division had only eight people. The initial effort in R&D was focused on formulating bulk drugs into dosage forms and on developing cheap processes to synthesize bulk drugs.

In the 1980s Ranbaxy began focusing on developing novel production process that would let it side step other company's process patents. In 1985 Ranbaxy found a novel way to manufacture the anti-ulcerant Ranitidine, the world's best selling drug and the generic version of Glaxo's Zantac. However, the real breakthrough in process R&D came with the development of an innovative novel process for Cefaclor. The molecule was owned by Eli Lily through a patent the firm had obtained in 1979. This antibiotic was one of the best selling drugs in the 1980s. Ranbaxy started work on developing a new seven stage process for the production of Cefaclor in 1988. Ranbaxy invested lot of resources to develop a new process for synthesising Cefaclor despite internal doubts about committing R&D resources to a product that was difficult to manufacture. The number of steps involved in synthesis of product, their potential for hazardousness and associated cost made the product too expensive for the Indian market. Also Eli Lily had filed more than 70 patents for process improvements to protect the drug from generic competition. But after spending three years and nearly Rs.20 million, Ranbaxy emerged as the only other manufacturer of Cefaclor. Dr. Parvinder Singh, former MD commented that,

"we moved through maze of over 70 process patents around Cefaclor to produce non fringing version of the molecule"(Annual Report, 1993).

Not only did Ranbaxy produce the product successfully but it also managed to obtain high yields from its process. Subsequently in 1992 Ranbaxy started a joint venture with Eli Lily for the manufacture and supply of Cefaclor. The development of a non patent- infringing process for the antibiotic Cefaclor in 1992 gave Ranbaxy international recognition and

huge profits. This success proved important for the future progress of innovative R&D in Ranbaxy.

R&D strategic direction			
Segment	**2004**	**2007**	**2012**
Generics	* * *	* * *	* * *
NDDS	*	* *	* * *
NDDR			* * *
Global Sales	**US $ 1 Bn**	**US$ 2Bn**	**US $5 Bn**

Fig 7.1 Ranbaxy's R&D strategic direction (stars indicate importance/direction in the segment) (Source: Annual Report, 2003)

On the heels of its success with Cefaclor and roughly in tandem with the vision 2003 exercise, Ranbaxy stepped up its R&D expenditures from 2% of sales to 5%. Dr. Parvinder Singh challenged Ranbaxy's top management team with his dream of transforming Ranbaxy into "an international, research based pharmaceutical company". He consistently questioned the imitative R&D mindsets in scientists and started establishing state-of-the-art multi-disciplinary R&D facilities at Gurgaon (near New Delhi), India. The company's new strategic intent was to ascend the research value chain and accordingly it began to establish capabilities in the areas of discovery research, delivery systems and clinical research (Fig 7.1)

Ranbaxy decided to focus on NDDS (Novel Drug Delivery Systems) and NDDR (New Drug Discovery Research) as key anchors of innovative R&D. Ranbaxy critically reviewed its R&D competencies and adopted a two stage approach, beginning with development of NDDS platform first and then followed by development of NDDR. Thus development of capabilities in NDDS will act as a stepping stone to development of NDDR capabilities. Therefore focus on NDDR/NCE (New Chemical Entities) is for long term value building and on NDDS for medium term growth. Ranbaxy's new drug delivery system focus is on

developing new ways of administering drugs at the diseases site through value added dosage forms and new platform technologies.

Ranbaxy gradually changed focus of R&D from process R&D to new initiatives in NDDR and NDDS. Over the years Ranbaxy has consistently increased R&D intensity from 2% of sales to 6 %, showing consistent commitment towards innovative R&D. It has emerged as one of the largest investors in R&D in the Indian pharmaceutical industry with R&D investment of Rs.2761 million in 2003. In earlier years, investment was largely directed towards the establishment of R&D facilities. Ranbaxy's has established three R&D facilities; two at Gurgaon and one at Noida.

The increase in R&D expenditure experienced by Ranbaxy can be seen more clearly from table 7.4. Ranbaxy's former R&D president summarises R&D investment as,

"we started R&D 20 years back and with very small investments every year we improved continuously. We invested in R&D whatever little we can invest but we increased our investments every year. It has not built in one or two years, it took us really a bit of time, 10-15 years where it is today".

In last decade Ranbaxy R&D investment gained momentum as company started funding basic research involved in finding new chemical entities through the revenues generated from generics business.

Table 7.4 Ranbaxy's R&D intensity and investment (Source: Annual Reports 1999-2003)

Year	R&D intensity	R&D investments (Rs million)
1993-94	5.9	192
1994-95	5.1	396
1995-96	5.3	427
1996-97	4.3	540
1997-98	3.9	608
1998-99	3.6	698
1999-00	3.6	843
2000-01	4.2	1193
2001-02	3.8	1266
2002-03	5.2	1921
2003-04	6.1	2761

Ranbaxy had no prior experience in basic R&D and initially building a strong, well focused inter disciplinary research team posed a major challenge. Dr. Khanna who was

head of Ranbaxy's R&D had some experience of drug discovery and that helped in building the foundations for innovative R&D. Ranbaxy's former R&D president explains,

"we got some people who have experience, then provided them infrastructure and built on that basis. We haven't got any one who is really perfect for drug delivery but we had some semi- perfect kind of people and then we said let's start. So with our own brain storming push and whatever is there we built".

In 1999 Ranbaxy registered its first success in innovative R&D with the development of once-a-day dosage for the Ciprofloxacin molecule. This improvement in dose administration promised greater patient-compliance compared to multiple dosages offered by the patent holder, Bayer and hence was a major step forward. Former R&D president explaining the Ciprofloxacin OD project comments,

"actually origination was when we made Cefaclor, bulk drug for Eli Lily and that I think we licensed in 1991-92. The total quantity we supplied for 5-7 years and we made huge profits. That was essentially a chemistry outcome in manufacturing bulk drugs. We always used to debate that we should have something similar in formulation which can give us this quantum profit like in Cefaclor".

The development of once-a-day formulation became Ranbaxy's first major innovative R&D product. Ranbaxy licensed the once-a–day technology to Bayer AG for US$10million for further development and marketing in select markets. In 2004 Bayer successfully launched 500mg and 1gm once-a–day formulation in US, based on delivery technology platforms developed by Ranbaxy, thereby triggering the milestone and revenue sharing payments.

Table 7.5 Ranbaxy's NCE pipeline (Source: Annual Report, 2003)

NCE pipeline			
Preclinical	**Phase I**	**Phase II**	**Phase III**
Urology (BPH)	**RBx 9001**		**RBx2258**
Anti- Malaria	**RBx11160**		
Respiratory diseases		**RBx7796**	
Bacterial Infections	**RBx003** **RBx7644**		

Ranbaxy's new drug discovery R&D focus now includes urology, anti-infective, respiratory, anti-inflammatory and metabolic disorders segments (Table 7.5).

Ranbaxy's first NCE, RBx 2258, for Benign Prostrate Hyperplasia (BPH), has been licensed to Schwarz Pharma AG of Germany and is presently undergoing Phase II clinical trials in India. Schwarz Pharma obtained the exclusive rights to develop, market and distribute the product in the US, Japan and Europe, while Ranbaxy retains rights for all other markets. In 2004 Ranbaxy received US $ 4 million milestone payment from Schwartz Pharma in addition to already received upfront payment of US $ 6 million. Ranbaxy's other promising drug candidate RBx 7796, anti-asthma molecule, is also undergoing Phase II clinical trials. Besides these, the company has other molecules in its NCE pipeline, which are at different stages of clinical development.

Despite having a few molecules in clinical and preclinical trial stages, Ranbaxy reached a critical stage by 2002 as bulk of its R&D was in generics. Ranbaxy needed more scientists with the experience in state of the art drug discovery technologies, particularly to cut down the failure rates. It also needed to take quick and clear decisions on several aspects of drug discovery like which diseases to concentrate on, techniques to employ etc. To fill those knowledge gaps Ranbaxy started hiring Indian scientists based in US/ Europe, working with multinational R&D laboratories. Former R&D president explains,

"we have brought a lot of them; I have brought a lot of them. Almost 20% population is from US".

The size and infrastructure in Ranbaxy's R&D, success of Ciprofloxacin OD and the credibility it gained form its global alliance with Eli Lily helped company in its efforts to encourage 'reverse brain drain'. In 2003 Ranbaxy hired Dr. Rashmi Barbhaiya, who was vice president of drug discovery in Bristol Mayer Squib (BMS) as its R&D director. He was closely involved in many contemporary drug discovery technologies in BMS. After Dr. Bharbhaiya, Ranbaxy hired Dr. Batra from Schering Plough Research Institute in the US, as a new vice president pharmaceutical development to lead the development of new chemical entities and new drug delivery research.

In 2003, under the leadership of Dr. Bharbhaiya Ranbaxy took some key decisions regarding future direction of its R&D. It decided to focus the research on a few key diseases which involve easy targets and relatively simple and short clinical trials like infections, metabolic disorders, urology, inflammations and respiratory diseases. In these therapeutic segments there is much less competition because many multinationals have been focusing on other areas of research like cardiovascular, anti diabetic or anti obesity. Ranbaxy decided to put on hold rational drug design strategy and instead choose analogue research as main new R&D strategy. Analogue research involves working on

predetermined targets for specific diseases to develop molecules that alter the target's mechanism in the diseased person. Therefore company decided against large scale investments in biotechnology, systemic biology and other biological areas like genomics or proteomics. It also decided not to invest in high throughput screening or to build a large library of potential drug molecules.

In recent years Ranbaxy has massively increased R&D staff to create a critical mass of scientists working in R&D. In 2004 Dr. Rajinder Kumar, previously global head of Psychiatry – clinical research & development at Glaxo Smithkline (GSK) took charge of Ranbaxy's R&D with responsibility of accelerating company's drug discovery effort. Ranbaxy's focus is now on recruiting the scientific staff to create critical mass in terms of different scientific disciplines involved in discovery research (see Table 7.6).

Ranbaxy has institutionalised the research review process in the company by setting up a science committee. In 1999 Ranbaxy set up the scientific advisory committee under the leadership of Dr. Nityanand, former head of Central Drug Research Institute, India. The terms of reference of science committee include R&D organisation structure, monitoring the R&D activities in global perspective and laying down the guiding principle for attracting, retaining and rewarding high calibre scientists as well as implementing a policy framework for collaborative R&D programmes.

Table 7.6 Ranbaxy's R&D employee strength (Source: Annual Reports, 1999-2003)

Year	Total number of people	No. of people in R&D	Scientists
1994-95	4703	325	
1995-96	4478	380	
1996-97	6131	456	
1997-98	5655	443	
1998-99	5469	498	330
1999-00	5347	490	410
2000-01	5784	512	410
2001-02	6424	580	474
2002-03	6297	700	583
2003-04	6797	919	650

Ranbaxy has also set up a US R&D facility to focus on three areas: clinical research, regularity affairs and to give commercial inputs on diseases, targets and compounds to be pursued.

7.2.3 Strategic R&D alliances

The other important feature of Ranbaxy's strategy for building capabilities in innovative R&D is collaborative research with national and international research institutes. In 2000 Ranbaxy put together a dedicated team of young professionals to explore and identify in-licensing/ out- licensing and co-development opportunities in areas of new technologies and value added products. Ranbaxy is strengthening its collaborative research initiatives through alliances with drug delivery companies, research institutes and international universities. According to Ranbaxy's Vice President, Corporate Planning,

"in case of Ranbaxy, collaborative research is linked with the outsourcing philosophy as well as filling up gaps in-house capability. It's linked to the number of factors; it's your own scientist's capabilities, their experience and exposure".

In case of Ranbaxy's drug delivery system research collaboration with UK universities and research institutes played a significant role in technology development. The senior scientist who led Ranbaxy's effort in Ciprofloxacin OD project credits collaboration with Dr. John Staniforth from University of Bath as one of the reasons behind the success of the project. Ranbaxy's patent for once-a-day drug delivery system lists Prof. John Staniforth as one of the applicants. Following on the success of Ciprofloxacin OD project, in 2001 Ranbaxy started collaboration with Vectura limited, a company founded by Prof. John Staniforth. Vectura is known for its expertise in application of particle science for the development of novel drug delivery systems to develop a novel cost effective, patent protected, oral controlled-release technology with potential application for a broad range of pharmaceutical compounds. In 2003 Ranbaxy entered collaboration with Institute of Nuclear Medical and Allied Sciences (INMAS) for screening and evaluation of formulations and drug delivery systems using Gamma Scintigraphy.

Following the collaborative R&D success in new drug delivery systems Ranbaxy created similar alliances for drug discovery research. In 2003 Ranbaxy entered into alliance with Glaxo Smithkline (GSK) to discover and develop novel therapies in Ranbaxy's four focus therapeutic areas. In a first of its kind of agreement in India, GSK will provide lead molecules that act on drug targets specific to Ranbaxy and GSK. Ranbaxy will deploy its chemistry team to optimise its chances of success. Ranbaxy will conduct the early clinical work which GSK will complete the development. In some cases Ranbaxy will develop its own molecule up to Phase II clinical trials and then GSK will carry out late stage development of that molecule.

Ranbaxy's other important collaboration in drug discovery R&D is with the Medicines for Malaria Venture (MMV) Geneva, in the development of anti-malarial drugs. Under this collaboration Ranbaxy's team of scientist will work together with University of Nebraska's

Medical centre, Monash University and the Swiss Tropical Institute to identify lead molecules. The development work from pre clinical to clinical studies will be carried out by Ranbaxy. The lead candidate from this programme, molecule Rbx1160 is currently undergoing clinical studies in the UK.

Ranbaxy's innovative R&D strategy has identified biological disciplinary areas like genomics, proteomics and systems biology for collaborative research. Ranbaxy plans to make up for its biological deficiencies by building network partnerships with overseas companies, research institutes and universities. In 2003 Ranbaxy collaborated with University of Queensland and Harvard Medical School, US to undertake research in biotechnology. In 2004 Ranbaxy signed a collaborative research agreement with Avestha Gengraine Technologies Pvt Ltd, to carry out project relating to construction of recombinant cell lines required for screening Ranbaxy's drug candidate.

Over the years Ranbaxy has established strong relationships with Indian research institutes. In 1999 Ranbaxy initiated seven R&D projects in collaboration with CSIR labs in various areas of innovative R&D. In 2003 Ranbaxy started a collaborative project with University Department of Chemical Technology (UDCT), Mumbai involving work on computer aided rational drug design and synthesis of new chemical entities. The cost of the project is jointly shared by UDCT, Department of Science and Technology (DST) and Ranbaxy.

In 2004 Ranbaxy signed an agreement with Anna University, Chennai to collaborate on drug discovery. Under this agreement, Centre for Biotechnology (CBT), Anna University would screen compounds from natural screens as well as synthetic sources. The leads from this programme will be optimised and candidates would be identified for further development, Ranbaxy would then conduct further clinical development on discovered leads. In the same year Ranbaxy entered into research collaboration with National Institute of Pharmaceutical Education and Research (NIPER), Mohali and Department of Science and Technology (DST), New Delhi, in the area of drug discovery.

In 2003 Ranbaxy formed a joint venture with Kasturba medical college to set up the clinical trial centre to build development phase capabilities.

7.2.4 Summary

Ranbaxy is aiming to achieve significant business presence in proprietary prescription products in advanced markets by 2012 and is therefore investing in innovative R&D to enable a transition from a generic focused company to a branded/specialty pharmaceutical product company. Ranbaxy is aggressively hiring senior scientists from overseas and practising collaborative R&D to become a research- based international pharmaceutical company.

7.3 Dr. Reddy's Laboratories (DRL)

Dr. Reddy's Laboratory (DRL) has emerged as the first Indian pharmaceutical company to discover a new chemical entity and license it to MNC pharmaceutical firm. In the last decade it has consistently ranked amongst the top ten pharmaceutical firms in India. Now the company has 15 manufacturing plants in India, 2 plants in UK and 1 in China. It has set up 23 subsidiaries for distributing and marketing pharmaceutical products in the domestic and international markets. DRL which started as a bulk drug manufacturer in the 1980s, moved to a formulation-focussed company in early 1990s, upgraded itself as a US focussed pharmaceutical company in the mid 1990s, and finally it is transitioning into 'a research based international company'. Since the start of its operation DRL has continuously sought to move up value chain in terms of pharmaceutical products, markets and capabilities.

Dr. Reddy's laboratories (DRL), founded by Dr. Anji Reddy in 1984, has grown into a fully integrated pharmaceutical company with an annual turnover of Rs. 20,081million (US $500 million) in 2003. Dr. Anji Reddy began his career with Indian Drugs and pharmaceuticals ltd (IDPL), a public sector company after completing his doctoral research from National Chemical Laboratories (NCL) India. At IDPL Dr. Reddy gained the hands on experience in the manufacturing and implementation of new technologies in bulk drugs. After working for six years, he set up two bulk drug companies called Uniloyds and Standard Organics in partnerships with two other colleagues. However, he decided to go alone and set up a new company called Dr. Reddy's Laboratories Ltd (DRL) in 1984. Dr. Reddy's competence was his focus on organic synthesis and under his leadership DRL successfully commercialised a variety of new technologies. After a few years, Dr Reddy developed a group of scientists with core skills in process research, which enabled DRL to develop processes for a number of molecules in a short span of time. DRL started as a bulk drug company and with the effort of Dr. Reddy it moved into the formulations business. In 1986 it started operations on branded formulations and within a year launched Norilet, DRL's first recognised brand in India. But big success came with launching of Omez, Omezaprozole which DRL managed to launch at 50% lower prices compared to other brands prevalent in Indian market at that time. DRL successfully reverse engineered many popular patented drugs to expand its therapeutic presence and within a year of its inception, DRL became the first Indian company to export bulk drugs or API to Europe. Dr. Reddy attributes entrepreneurial thrust and initial success of DRL to the 1970 patent law,

"we are products of that (1970 law). But for that, we wouldn't be here. It was good for the people of India, and it was good for this company" (Forbes, 2001).

In case of DRL the transition from predominantly API focused firm to being a formulation company took place in 1994.

With India's shift from current process patent regime to post 2005 product patent regime, the broad strategy of DRL is to develop new molecules for licensing through innovative R&D and target advanced market for speciality generics product. Dr. Reddy noted,

"the Indian pharmaceutical industry benefited in the early years due to lack of a patent regime. Now that the party is over, there is likely to be a lot of consolidation towards 2005. Indian companies need to focus on opening up new markets and we took a step in that direction few years ago" (Industry 2, 2003).

DRL strengthened its Indian operation by acquiring American Remedies limited in 1999 and merging Cheminor Drug Limited (CDL) with DRL in April 2000. This acquisition and merger made DRL the third largest pharmaceutical company in India, after Ranbaxy and Glaxo (I) ltd. DRL post merger was a fully integrated pharmaceutical company, covering the full spectrum of pharmaceutical products, which included bulk drugs, intermediates, finished dosages, chemical synthesis, diagnostics and biotechnology. DRL merged Cheminor Drug Limited (CDL) with primary aim of supplying APIs (active pharmaceutical ingredient) to the technically demanding markets of North America and Europe. Cheminor was part of DRL from 1984 and this merger gave DRL entry into value added generics business in the regulated markets of APIs.

7.3.1 The generics strategy

DRL began its major international operation by entering Russia through a joint venture with Biomed in 1992 and in 2002 DRL converted JV into its 100% subsidiary. DRL started targeting US generic market by building state of art manufacturing facility in 1994. In three years DRL filed its first ANDA (abbreviated new drug application) in 1997 for Ranitidine 75mg tablets, and improving on that, in 1999 it submitted a Para IV application for Omeprazole. But the big achievement of DRL generic foray came in 2001. In 2001 DRL became the first Indian company to launch a generic drug, Fluoxentine with 180 day market exclusivity in US. As a result of market exclusivity DRL's international sale of Fluoxentine 40mg, a generic version of Eli Lilly's Prozac increased massively. The generic turnover touched $23.2 million for the third quarter of 2001, with Fluoxentine contributing 87% of these sales.

In January 2003 DRL launched Ibuprofen tablets 400, 600 and 800 mg in the US under its own brand name. Ibuprofen became the first generic product to be marketed under DRL brand name and thus represented a significant step in DRL's efforts to build a strong and

sustainable US generic business. Direct marketing of Ibuprofen was the first step in building DRL's fully fledged commercial organisation in the US market.

In 2002, DRL started its European operation by acquiring two pharmaceutical firms in UK. The acquisition of BMS Laboratories and its wholly owned subsidiary, Meridian UK allowed DRL to expand geographically and gave company an opportunity to enter the European market.

Table 7.7 DRL' generic product filings (Source: Annual Report, 2003)

Year	DMF (API)	ANDA (Formulation)
Till 2000	18	
2001	8	8
2002	14	14 (Para IV -10)
2003	16	13
Total	56	35 (Para IV – 24)

By 2003 DRL filed 56 DMFs (drug master file) and 35 ANDAs applications with USFDA, showing strong capabilities in innovative process R&D and regulatory management (see Table 7.7). Mr. G V Prasad, Managing Director of DRL summarises the company's journey towards generics,

"at DRL our starting value proposition was world class skills in synthetic organic chemistry. We started as a bulk, API company. Through our experience in India we started tapping export opportunities in less regulated markets and in the early 1990s shifted focus to the US and other regulated markets. That's how we used the value proposition to evolve into a global provider of bulk actives. We started moving up the value chain by building on our chemistry skills through vertical integration into finished dosages (formulations). The move into generics business was not an easy decision. Leveraging the API advantage, DRL has built an exciting pipeline for generics business" **(Prasad, 2003).**

In 2004 DRL acquired Trigenesis Therapeutics Inc; the US based private dermatology company. This acquisition gave DRL access to certain products and proprietary technologies in dermatology segment.

7.3.2 Research & Development

Recognising the importance of innovative basic research in the post 2005 Indian scenario, DRL built the Dr. Reddy's Research Foundation (DRF) in 1992. DRF is exclusively dedicated to research in area of new drug discovery and became the first organisation in the Indian pharmaceutical private sector to take up basic research.

The main objective of setting up this foundation is to discover and develop new chemical entities in selected therapeutic areas. Dr. Anji Reddy said,

"I made up my mind that we can get into drug discovery and took the plunge on 6th November, 1993. We jumped into discovery with a budget of about Rs. 65 millions" (Reddy, 2004).

The companies which are part of DRL group commit sizeable resources to support this state of the art 'research foundation'. For two years from 1991 to 1993 DRF invested heavily in building the physical infrastructure and from 1993 it started recruiting R&D staff. The foundation currently has teams of experts from different disciplines such as: medicinal chemistry, organic synthesis, fermentation, biochemistry, pharmacology and tissue culture.

DRF started work on drug discovery under the leadership of Dr. Reddy and a core group of senior scientists. There were very few scientists with experience of drug discovery in the Indian industry or academia. Therefore DRF build the core team for discovery research with 4 scientists who had the experience of drug discovery in multinational R&D. Dr. Venkatswarlu, DRF president till 2000, had experience of working in Ciba Geigy, Hoechest and SmithKlime Beecham. Dr. Rajgopalan, pharmacologist and current president of DRF, whom Dr. Venkatswarlu recruited, previously worked on drug discovery in Hoechest. Dr. A K Sadhukam had experience of microbiology in Smith Kline Beecham and Dr. G Om Reddy came from Astra - IDL. Out of this core team three were in discovery research and had the requisite experience of the complexities involved in drug discovery. This core group along with Dr. Reddy were responsible for introducing scientific programmes, inducting people and making them productive.

In the beginning DRF's drug discovery research strategy revolved around analogue research and created initial success for the company. Dr. Reddy explains,

"I began looking at molecular structures and realise to my surprise that many players, including some of the global majors, were just tinkering around with the molecular structure. Seeing this I realised that if it takes to discover drugs, then we could also be in race" (Business Today, 2001).

In three years of starting innovative research DRF discovered one of the most potent glitazones, Ragagltizar. A Japanese company Sankyo already discovered class of

compounds called glitazones that sensitises the body to insulin. Dr. Reddy got interested in the activity of glitazones and pushed his team to come up with better molecules. DRF scientists researched the activity of glitazones and came out with two new molecules, Ragaglitazar and Balaglitazone (DRF 2593). DRL has licensed the molecule Balaglitazone (DRF 2593) to Novo Nordisk. This molecule has shown excellent anti-diabetic activity in Phase II clinical trails and now Novo Nordisk is planning to take it to Phase III clinical trials.

Soon DRF began evaluating its R&D capabilities and started hiring scientists to fill knowledge gaps (see table7.8). Dr. Anji Reddy explains,

"in year 2000, we began to reflect on our inadequacies. It is one thing to bring NCEs to development by analogue research – but the path breaking developments in science including the unravelling of human genome, was paving the way for newer hitherto unknown targets in drug discovery. We decided to get into this area and started scouting for talent all over the world" (Reddy, 2004).

DRF focused on hiring fresh scientists to work in discovery R&D and identified Indian students studying abroad on doctoral and post doctoral courses as one of the main source of talent. DRF's former R&D president elaborates,

"our target was returning Indian students who have gone abroad to do either PhD or post docs. They were returning and were very good. Actually for 90% of DRF's R&D workforce, it was their first job, whether a bench chemist or vice president, first job in the industry. Since we recruited all fresher, it was easy to mould them. So what we did from day one became the practise. No one had experience of reverse engineering and all were from universities or NCL or NIH. They were not into reverse engineering and it is a fact that 'reverse engineering' mindset has not come in way of innovative R&D".

Table 7.8 DRL's R&D employee strength (Source: Annual Reports, 1998-2003)

Year	Total number of people	No. of people in R&D
1998-99		
1999-00	2100	229
2000-01		
2001-02	5500	500
2002-03	5852	725
2003-04		

Over the years DRL has consistently increased the R&D intensity of the firm but it gathered momentum in late 1990s as DRL started spending nearly 5% to 8%of its turnover on R&D compared to industry average of 2-3% (table 7.9). During 2003-04 DRL increased its investment in R&D initiatives to about 10% of total revenue against 7.6% spent in 2002-03. This is highest R&D investment to sales ratio in Indian pharmaceutical industry.

Table7.9 R&D investment of Dr. Reddy's Laboratories (Source: Annual Report)

Year	R&D intensity	R&D investments (Rs. Million)
1998-99	2.15	133
1999-00	2.69	179
2000-01	4.22	415
2001-02	6.29	980
2002-03	7.7	1338
2003-04	10	1910

DRF currently has 8 NCEs in various stages of development. Research thrust at DRL is focused towards anticancer, anti diabetes, cardiovascular drugs and anti infective (table 7.10). In 2003 DRL commenced its first clinical trial programme in Canada on DRF 10945 for the treatment of dyslipidemia. Now DRL has four molecules in clinical development and another four in preclinical stages of the development. DRL is pursuing the clinical development of three molecules on its own while fourth DRF 2593; the licensed molecule is now developed by Novo Nordisk. This is in line with DRL's strategy of investing in own discovery molecule up to Phase II and then pursuing licensing opportunities. Through this route DRL is building in-house capabilities for drug development as well as enhancing the value of new chemical entities. In the licensing deal with Novo Nordisk, DRL got upfront payment and will also be receiving milestone payments after successful completion of different phases of the clinical trials. Novo Nordisk will take up clinical trials, the packaging and global marketing of drug while DRL will be the sole global manufacturer of the drug.

DRF is planning to take DRF1042, an anti cancer molecules to market on its own. DRF 1042 is a novel orally active camptothecin analogue and is currently undergoing Phase II clinical trials in India.

Table 7.10 DRL's NCE pipeline (Source: Annual Report, 2003)

NCE pipeline				
	Preclinical	Phase I	Phase II	Phase
Metabolic Disorder	DRL 11605	DRF 10945	DRF 2593	
Cardiovascular Disorder	RUS3108			
Cancer	DRF 5265	DRF 1644	DRF 1042	
Bacterial Infections	DRF 13792			

DRF has put lot of emphasis on attending and presenting its work in different conferences. The company views it as an important constituent of creating stimulating R&D environment that encourage creativity and innovative thinking. Scientists in DRF patent their inventions globally and are encouraged to publish their research findings in some of the foremost peer reviewed scientific periodicals and conferences around the world. In 2001 DRF announced a new anti diabetic molecule at the American Heart Association's conference while in 2002 it showcased its anti bacterial molecule at the ICAAC (Inter-science Conference on Antimicrobial Agents and Chemotherapy) in US. Former R&D president explains,

"we are publishing; we have more than 100 publications. Last year in international conference on chemotherapy and microbiology, we had 10 abstract acceptances. This year there was American Diabetic Association conference, we had 4 presentations. The thinking behind that is first of all, we need to showcase our science. There is no point in keeping it by chest, we need to showcase. It also stimulates scientists thinking. First, it is promoting a different set of interactions. If our people have gone and made presentations in a conference which 1000 scientists are attending, then its validation of our science. People come, ask questions and our people stand up and give answers. All this adds, first of all to scientist's personality development, exposition of our sciences, showcases our work and also learning from other scientists' working".

Till 2004 DRL has published more than 110 research papers in various peer reviewed international and national scientific journals. Dr. Reddy summarises DRF's publishing philosophy,

"I have found that in managing science, especially drug discovery, one need to temper the commercial imperative with scientific wisdom. When well meaning friends discouraged my forays into drug discovery, I told to my scientists, if we are not able to discover new drugs, at least we will definitely publish research papers in reputed journals"(Business India, 2001).

The other significant aspect of DRF's R&D set up is the extensive arrangement for review of its innovative research. For external review DRF has set up a scientific advisory board with best of international and Indian scientists to generate international level project reviews, advice and interactions. Eminent scientists like Dr. Mehta, chemist and molecular biophysicist; Dr. Balsubramanyam, ex director of CCMB(Centre for Cellular and Molecular Biology) ; Dr. Shyam Parthsarathy, anti-oxidant specialist; Dr. K Janardhan Reddy, originator of PPAR concept; Dr. Peter Houton from St. Jude's medical hospitals and Dr. Ashok Ganguli, makes up the DRF's scientific advisory board. This board meets specifically twice a year and works as a forum to which DRF scientists expose their ideas to international experts, outside boundaries of the company.

Internally also, DRF's top scientists regularly conduct review meetings, in some projects on a weekly basis. Apart from that, on a monthly basis there is monthly report; monthly reviews where each scientists makes the presentation on what they have done, what they plan to do. This is critiqued, peer reviewed and action plans are formulated.

DRF is launching many initiatives to retain, train and develop its manpower. These initiatives are driven by a three pronged objectives: technology, entrepreneurship and globalisation. Looking outside the pharmaceutical industry DRL adopted the revolutionary human resource practices present in Indian IT companies. DRL following the Indian software companies' human resource philosophy launched different initiatives like performance linked pay, culture building activity and leadership development programmes (Business Today, 2003). DRL also established a learning centre in 1998 to conduct various on the job learning and development programme for its employees. DRL has signed a memorandum of understanding with Birla Institute of Technology and Sciences (BITS) to promote educational and research activities in the areas of chemistry, pharmacy and biotechnology. BITS operates an off campus centre at DRL and conducts educational programmes designed to meet the development needs of DRL's employees. In 2003 DRL organised convocation and 61 employees were awarded MSc degrees in pharmaceutical operations and management and MSc in pharmaceutical chemistry.

DRL is continuously organising special programmes to give technical staff intellectual property skills and project management skills.

7.3.3 Globalisation of innovative R&D

DRF after establishing discovery research in Hyderabad wanted to introduce modern skills such as drug discovery based on genomics and proteomics. It wanted to move from analogue research towards the target based discovery or rational drug design but struggled with this change. Former R&D president described the situation as,

"we could not recruit the requisite skills because it's not the one scientist, you need whole team and we could not do this for the period of three years. We located scientist but 1 or 2 may be willing to come out but they had inhibitions and they needed lot of time and they were unable to take decisions. Then we decided there is no point in waiting. We can not bring people here; we will move our lab there".

Therefore in 2000, DRF set up a lab in Atlanta, US dedicated to discovery and design of novel therapeutics. The lab is called as Reddy US Therapeutics Inc (RUSTI) and primary aim is to conduct drug discovery using molecular genomics and proteomics approaches for next generation drugs. Dr. Reddy explains,

"I went to US because it was necessary for my survival. I couldn't get the talent for biotech research in India" (Business World, 2002).

DRL recruited Dr. Uday Saxena as CEO of its Atlanta subsidiary and within two months RUSTI built a team of 12 scientists. In few years RUSTI developed a technology platform and a discovery approach based on the cell matrix signalling (CMS) pathway. A lead molecule, RUS3108 is currently in the late preclinical stage

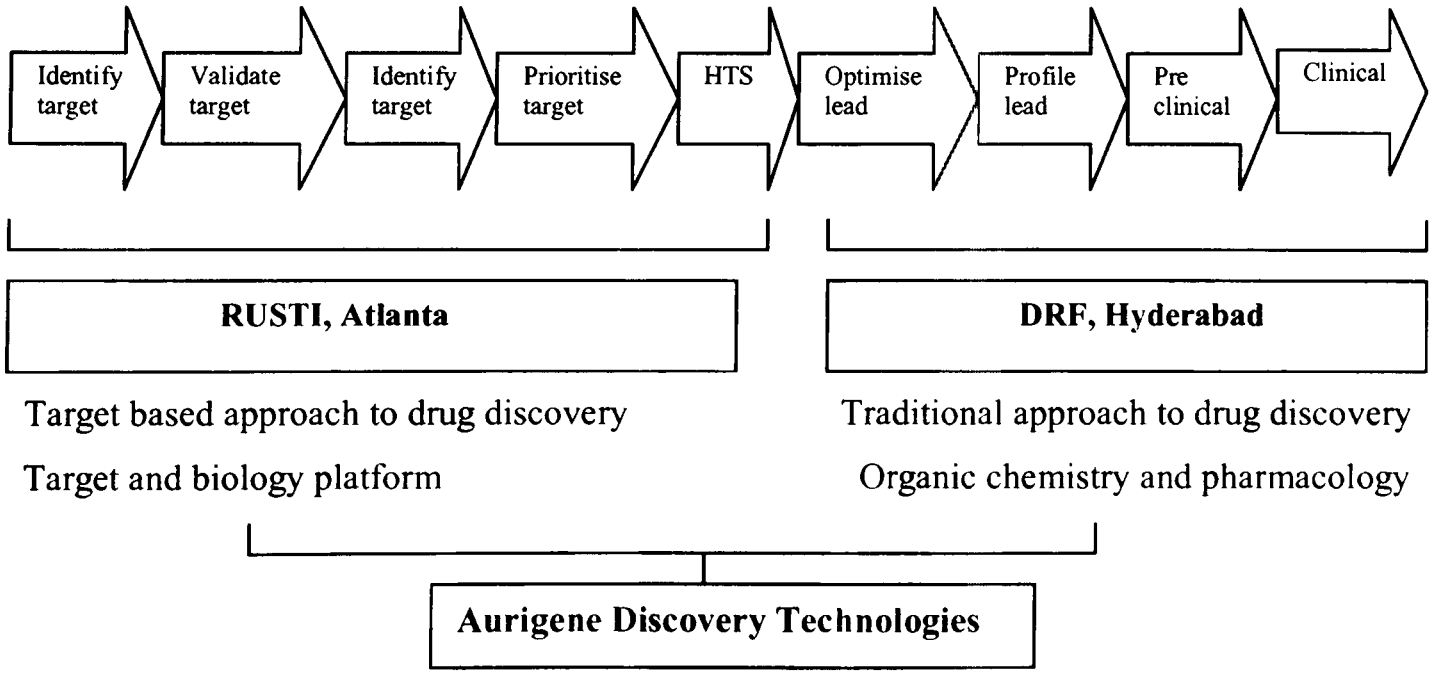


Fig. 7.2 Building structural biology and medicinal chemistry skills through structured based drug design (Source: Annual Report, 2002)

DRF raised the funds for international expansion of R&D through IPO (initial public offering) in US. In 2001 DRL completed its US initial public offering of US$132.8 million ADS (American depository shares) issue and listed on the New York Stock exchange. The funds collected from US IPO were diverted into the international expansion of R&D.

Aurigene is another research based company promoted by Dr. Reddy's laboratories with an investment of Rs 111million in 2001. It is launched as a contract research company to provide discovery services to the pharmaceutical and biotech companies. By setting up the Aurigene DRL have direct access to discovery research out of three labs (Fig. 7.2):

a. Dr. Reddy's Research Foundation (DRF),

b. Reddy US therapeutics (RUSTI) at Atlanta and,

c. Auriegene at Bangalore and Boston.

DRF arranges the visits of scientists working in India to its labs in Atlanta and Boston. Former R&D president comments,

"we created important resource by opening lab in US. We wanted an address in US, in many ways it is very useful to us. Second, America is home for doing research and we thought it will allow us exchange scientists between here and there; cross fertilisation of cultures, ideas and then it will make our R&D truly global. When our scientists go for conference in US, they spent few days in the Atlanta and vice versa. Their scientists come and we want to have more exchange programmes. A scientist from there can come back here and work here for several months".

In 2003 DRL invested Rs. 251.3 million in equity capital of Bio Sciences ltd. In 2004, DRF celebrated its 10 year anniversary by organising an international symposium on drug discovery called Pharmacophore 2004, addressing the symposium Dr. Reddy said, "analogue research first and target based discovery next – we have forayed into both".

7.3.4 Strategic R&D alliances

DRF has initiated a variety of R&D alliances and collaborations with Indian as well as international research institutes, universities and companies. In the beginning DRF entered into alliance with the Centre for Cellular and Molecular Biology for utilising its facilities in the pre –molecular stage research. DRF collaborated with other premier Indian research institutes like UDCT (University Department of Chemical Technology, Mumbai), National Institute of Nutrition and Indian institute of Sciences. Over the years DRF has built R&D links with international research institutes, universities especially in the US to support its own drug discovery research. In the past DRF had alliance with North Western University

medical school in Chicago, National Cancer Institute, and National Institute of Health. which played an important role in DRF's learning about intricacies of particular therapeutic segments. These interactions are used to augment DRF's capabilities and fill R&D gaps; what DRF couldn't do at home, it got things done from there. Former R&D president explains nature of interaction,

"actually we have deputed one of our scientists in North West Medical School, to go and work with professor who is an inventor of or who originated PPAR concept. He went and spent more than two years and he has written two publications also and we are very happy about it".

DRF has licensed its molecules to MNC firms like Novo Nordisk, Novartis and these licensing agreements have also proved to be effective source of learning. Apart from financial gains these partnerships gave DRF an opportunity to learn new capabilities through joint working in the project. According to DRF R&D president,

"whenever we have licensing agreements with MNCs, we not only exchange data but we also exchange information. Then we sit down, we participate in some of things of the project and then learn things from other companies. It is continuous process and that is how we always structured our deals. So it is continuous education".

Although DRF progress in innovative R&D is quite remarkable, it also had fair share of failures. In 1998 DRF signed the agreement with Novo Nordisk to develop and market pharmaceutical products of its first molecule, Ragaglitazar. However in 2002 adverse effects appeared during clinical trials and Novo Nordisk abandoned research on the molecule and decided to work on another DRL molecule, Balaglitazone. In 2002, DRL granted exclusive rights for the development and commercialisations of DRF 4158 to Novartis Pharma AG, however in 2003 Novartis opted to replace dual acting insulin sensitizer, with other follow up compound. However according Dr. Reddy this proved to be an important learning experience and led to a change in company's licensing policies; DRF decided to out license the molecule only after completion of Phase II of clinical trials DRF's former R&D president who led company's R&D effort from the beginning till 2002 summarises efforts at DRF saying,

"I think this is greatest thing – creation of world class resource from scratch in a location away from the mainstream of pharmaceutical R&D, in the remote corner where we didn't even have patent regime".

7.3.5 Summary

DRL initially started as a manufacturer of bulk actives and using process development skills DRL developed several bulk actives and finished dosage. Then DRL moved into generic products targeting the highly regulated but very profitable markets in advanced countries. From 1990s DRL started developing capabilities in innovative R&D under the leadership of core team of experienced scientists and by hiring teams of fresh scientists to work with them. DRL expanded its R&D overseas and formed collaborations with research institutes and universities. Former R&D president of DRF comments on company's R&D efforts,

"in fact even before we truly globalise our marketing, we globalise our R&D which nobody has done. We are the first and our experience is fantastic".

7.4 Wockhardt Ltd

Wockhardt is now ranked among the top ten companies in India and has developed comprehensive expertise in manufacturing and marketing of pharmaceutical and biotechnology products. Wockhardt's product portfolio includes pharmaceuticals (bulk drugs and formulations), medical nutrition, Agri-sciences and hospitals. Wockhardt ltd was started by Khorakiwala family in 1959 as a small pharmaceutical distribution and selling entity. The company set up its first formulation plant in 1977 and soon established a bulk drug plant in 1983. Now Wockhardt has 8 manufacturing plants in the Aurngabad – 6 in the new biopharmaceuticals complex in addition to 1 each in Chikalthana and Waluj. In 1998 Wockhardt acquired Merind Pharma and became one of the largest producers of Vitamin B12 in Asia. In 2004 Wockhardt commissioned state of the art production facility dedicated to the manufacturing of only biotech products.

The company went public in the year 1992 and since that it has consistently shown impressive growth. The turnover of the Wockhardt in 2003-04 was Rs. 7671 million and out of that international sales contributed 57%. In international sales, European market contributed 37%, the US market contributed 10% and remaining 10% came from the rest of the world.

Wockhardt's post 2005 strategy is based on three dimensions: a. Research and development, b. Domestic business and c. International business. In 2000, Wockhardt's split up the pharmaceutical business from the agro-chemical, I.V. Fluids and hospital business into two divisions: Wockhardt Life Sciences and Wockhardt Ltd. The aim of this restructuring exercise is to allow Wockhardt Ltd to concentrate more on building skills and capabilities in the pharmaceutical business while Wockhard life sciences will strongly focus on managing businesses related to agricultural sciences, parentals and hospitals. The company is moving ahead with a business strategy which involves using innovative R&D for moving up the value chain in both the generic and biotechnology segments.

7.4.1 The generics strategy

Wockhardt started targeting international markets in the late 1990s. It entered UK market by acquiring Wallis Laboratory, a UK based company, in 1998 and in 2003 Wockhardt acquired another UK based pharmaceutical company CP pharmaceuticals. In 2004 Wockhardt streamlined its European operation by selling Wallis's manufacturing plant to Bristol Laboratories and shifting some of manufacturing operation of Wallis to CP Pharmaceutical's plant in UK and rest to company's Indian plant. Wockhardt is also investing £1 million for up-gradation of CP pharmaceutical plant to make it company's largest overseas manufacturing base and would eventually become a manufacturing base

for Wockhardt's European operations. Wockhardt is now the largest Indian pharmaceutical company in the UK and among the top 10 generic pharmaceutical companies in the UK.
In 2004 Wockhardt took over the business of German pharmaceutical company 'esparma'. GmbH to enter Germany, the largest generic drug market in Europe. Esparma has a portfolio of 135 marketing authorisations, of which 67 are in Germany. The company also has nine international patents and 94 trademarks. This acquisition gave Wockhardt increased depth in product portfolio and helped company to strengthen its presence in the European business.

Table: 7.11 Wockhardt's generic product portfolio (Source: Annual Report, 2003)

Year	ANDA	DMF
2001-02	1	2
2002-03	6	23
2003-04	10	7
Total	17	32

Wockhardt recently launched its US operation by starting Wockhardt Americas Ltd and now has its own marketing and regulatory teams based in US. In 2004 Wockhardt relocated key officials handling corporate scientific affairs and intellectual property management from Mumbai to newly established subsidiary in the US. Wockhardt's US strategy is based on launching formulation products through ANDA route and till 2003 it has filed 17 ANDA applications with USFDA (see Table 7.11). So focus is on the ANDA rather than to file DMF (drug master files) as it doesn't intend to sell API in US and Europe markets. Wockhardt currently sells four products in the US – ranitidine, enalapril, bethanecol chloride and captopril.
Currently 80% of Wockhardt's international business comes from developed markets of the US and Europe, while 20% comes from the rest of the world.

7.4.2 Research & Development

Biotechnology is Wockhardt's R&D thrust area and with three exclusive products in the market, the company has been the front runner in the biotechnology research. From early 1990s company is spending 20 -30% of its total research budget on biotech R&D. In 1995 Wockhardt formed the joint venture with the German firm Rhein Biotech for manufacturing of hepatitis B vaccine and in 2000 company launched its first biotech product, a hepatitis B vaccine called Biovac-B. This joint venture helped company to

develop manpower trained in biotechnology R&D and provided access to crucial know-how. In 2001 Wockhardt indigenously produced a drug called erythroprotein (EPO) for severe anaemia. In India, erythroprotein was produced for the first time using genetic engineering methods. However for Wockhardt important milestone in biotech R&D came with development of human insulin. In 2003, Wockhardt launched human insulin named, Wosulin. Wosulin become the first Human insulin to be made indigenously by an Indian company. The company is fourth in the world – first outside US and Europe – to develop, manufacture and market this life saving drug used in diabetes.

Wockhardt is also developing a generic version of biopharmaceutical Interferon alfa 2b and which is currently undergoing Phase III clinical trials. The company plans to make a foray into global markets on the strength of its biotechnology product portfolio. Building on these biotechnology capabilities Wockhardt is aiming to develop competencies in genomics and proteomics to support its ambitious new drug discovery programme.

Wockhardt set up its R&D centre at Aurangabad in 1994 and entered the field of new drug discovery research in 1997. From 1998, Wockhardt has been consistently investing into its R&D activities and is one of the top R&D investors in Indian pharmaceutical industry (see table7.12).

7.12 Wockhardt's R&D intensity (Source: Annual Report, 1999-2003)

Year	R&D intensity	R&D investments (Rs. Million)
1998-99	10.9	424
1999-00	4.6	416
2000-01	7.2	402
2001-02	6.2	402
2002-03	6.2	460
2003-04	7.9	604

Although Wockhardt embarked on innovative R&D programme little later than its other major Indian competitors like Ranbaxy or DRL, it achieved impressive results in the chosen therapeutic research area: anti-infective.

Like other innovative Indian pharmaceutical firms Wockhardt's innovative R&D strategy is based on using techniques of analogue research to find new chemical entities. According to Wockhardt's head of pharmacology,

"right now it's more of analogue but slowly it would be original because we need to train our people to develop absolutely new pharmacore and that takes time. So coming out with new pharmacore will take 10 more years. Most companies do analogue research only; every second day you don't get a new pharmacore".

However, unlike other Indian companies, Wockhardt has decided to focus only on the anti-infective therapeutic segment, as the main thrust area in new drug discovery R&D. Wockhardt's head of anti-infective R&D, explained the rationale,

"even though possibly we could have handle at least one more therapeutic area, easily but very conscious and deliberate decision was taken to stay focus in one therapeutic area because we wanted to develop skills of that therapeutic area in greater depth and ultimately the plan or the vision is, to leverage those in-depth skill sets in long run. We thought let us stay focus in one therapeutic area but go in depth and leverage the depth, knowledge depths over a period of time. Which in a very remarkable way it demonstrated, where in shortest time after starting the programme, we were able to come up with a molecule in the clinical development".

Wockhardt's drug discovery programme has yielded several lead molecules (table 7.13), one of which, WCK-771, a broad spectrum antibacterial, has completed Phase I clinical trials and is entering the next phase of trials. The new chemical entity WCK771 will be useful in treating Methicillin and Vancomycin resistance life threatening infections and sepsis. The other chemical entity WCK -1152 has completed pre-clinical trials and a patent has been filed. WCK-1152 has been found effective for treating hospital and community-acquired respiratory tract infections. In case of WCK- 1457, a new chemical entity with potent activity against Vancomycin-resistant enterococci, the toxicity studies in progress.

Table 7.13 Wockhardt's NCE pipeline (Source: Annual report, 2003-04)

	NCE pipeline			
	Preclinical	**Phase I**	**Phase II**	**Phase III**
Anti-infective	**WCK - 1457** **WCK -1152**		**WCK- 771**	

Wockhardt's has built in-house clinical research facilities and a sixteen-member team is looking after development phase involved in commercialisation of innovation. The team successfully undertook Phase III clinical trials for Wosulin as per international guidelines. These trials involved monitoring 350 subjects at nine different centres. The clinical research team has also successfully completed Phase I clinical trials for Wockhardt's new chemical entity, WCK-771 as well as preclinical studies on WCK -1152 and filed an IND application.

Unlike other innovative Indian firms, Wockhardt is planning to develop the molecule into later phases of clinical trials rather than license it at earlier stages. According to head, of anti-infective R&D,

"we thought that we will make R&D neither as a business centre enterprise nor as a source of immediate revenue, like how some companies are at very early stage starts hawking their molecules and they say we have these, and that and anybody has interest please contact us. We said we will not do as much as hawking at early stage and rather we will take R&D as a serious effort for ultimately developing a new product for Wockhardt itself to the market".

Wockhardt has put together a core team for discovery R&D by hiring scientists from universities, research institutes or other Indian companies. Wockhardt started building team for innovative R&D by hiring Dr. Noel De Souza, a scientist with extensive experience in innovative pharmaceutical R&D. Dr. De Souza was R&D president at Hoechst's Indian research centre for more than 10 years. To lead its biotechnology effort Wockhardt hired Dr. M K Sahib from Central Drug Research Institute (CDRI) institute. Wockhardt's anti-infective research programme accelerated after it hired Dr. Mahesh Patel from Ranbaxy Laboratories. Dr. Patel had experience in drug discovery due to his working experience in Hoechst Research Centre with Dr. De Souza. In 3 years from 2000 scientific staff working in Woclhardt has increased from 220 to 400 (table 7.14). But Wockhardt also faced some problems in attracting research talent from overseas. According to Wockhardt's head of pharmacology research,

"if you pay well, you can attract the people. Now it's not the question of salaries but also question of where you are located. Like Aurangabad is not a very great place, so people coming from outside or abroad, they don't prefer to stay here".

7.14 Wockhardt's R&D employee strength (Annual Report, 2003)

Year	Total number of people	No. of people in R&D
2000-01	2300	220
2001-02	2700	300
2002-03	2805	350
2003-04	2928	400

Wockhardt's core team working on innovative R&D thus have roots in Indian research institutes or Hoechst Research Centre in India. Wockhardt's head of anti infective research explains that,

'there are few people like me, I have also been trained from abroad but I don't want to attribute to what work I did here to my international training, very little role of that. I would rather attribute the success of programme which we had here in Wockhardt to my initial training at Hoechst for 21 years rather than so- called training abroad. I was earlier part of drug discovery team at Ranbaxy, there I joined from Hoechst. We created entire team, a set of people and gain significant amount of understanding. Then when I came to Wockhardt from Ranbaxy, many of the colleagues preferred to join me here. So I think 7 or 8 people from Ranbaxy also came here, formed core team of researchers and around which further sub teams were built".

Wockhardt's R&D is divided around three research units; basic research, biotechnology and formulation. These three research units are headed by different scientists and pharmacology department provides support to these three departments. The research projects are managed by using matrix structure rather than hierarchy. Wockhardt's head of pharmacology explain,

"how Wockhardt works is a beautiful system. Its more of a matrix system rather hierarchy system, hierarchy system is also there because people are there at different levels but it's not something that very hard and fast rule that this person will report to that person. On paper they do report to each other and everything is fine, but it is an open matrix system and anyone can walk into any lab, talk to colleagues, and get the data; nothing is confidential except the structure".

Wockhardt is putting lot of emphasis on coordinating and integrating knowledge flow between chemistry and biology. The company has set up cross-disciplinary teams to lead

various research projects. Both chemistry and biology have 4 sub teams and this 4 plus 4 chemistry and biology sub team handle every project, almost from inception to end of preclinical stage (fig 7.3). According to head of pharmacology,

"we do have monthly meetings for biology group where chemistry group goes, we have some meetings with chemistry group, where biology group goes and everything is coordinated. We have group leaders at different levels and we have director biology and we have director chemistry and it works in very integrated ways".

Clinical team is separate but according to Wockhardt's R&D president this arrangement creates a seamless structure for the smooth movement of people from one project to another. It also allows many people from each team to act as a linkage between pre clinical and clinical.

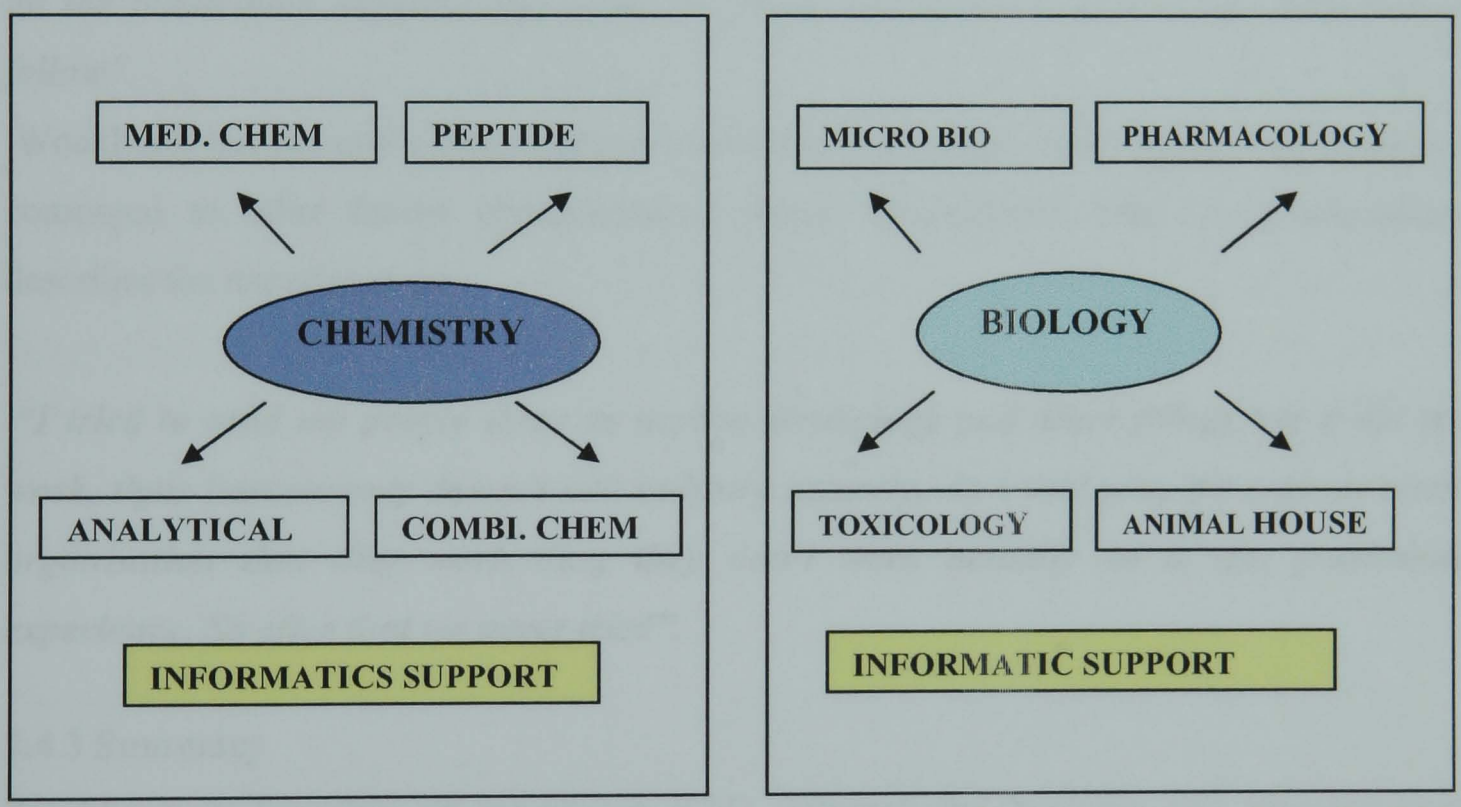


Fig 7.3 Wockhardt's research project structure (Source, Patel, 2003)

The chairman plays an important role in selection of different R&D projects and periodically reviews all the research projects. Innovative R&D projects are reviewed informally and formally almost on weekly basis. Wockhardt's head of anti-infective R&D explains,

"a formal review process that is there with chairman but when it comes to the scientist's level, its needs to be and also done in very informal way, so that it gets handled as part of natural process. Wockhardt also uses the external consultant but only when it is necessary".

Adds head of pharmacology,

"more or less internal (review is done) but we do have (arrangement for external expertise) as and when required. If an external expertise is required, then we have contacts in place. They either are invited to India or data is sent to them or we meet them at common places in Europe somewhere; half the way we travel, half way they travel. In Wockhardt whichever way we want to do it, we can do it".

In terms of conferences publication Wockhardt has been very active, specifically in anti infective therapeutic area. Company is encouraging its scientists to attend and present their work at prestigious scientific conferences and meeting. It annually participates in the International conference on Antimicrobial Agents and Chemotherapy (ICAAC). Wockhardt's R&D president suggest,

"we make regular presentation into it, scientists participate and we have publication but all the publication happens only after the patent are in place, that is one thing we all follow".

Wockhardt has put much less emphasis on R&D collaboration with Indian R&D institutes compared to other Indian pharmaceutical firms. Wockhardt's head of pharmacology describes the experience as,

"I tried to send my people there in nephro-physiology and other things but it did not work, their bureaucracy doesn't suit industry actually. As I told you, it's a government organisation that they work like; they don't work actually so it was frustrating experience. So after that we never tried".

7.4.3 Summary

Wockhardt is focusing on innovative R&D, international business and biotechnology products as pillars of its post 2005 strategy. Over the years Wockhardt has consistently invested impressively in R&D and emerged as one of top R&D spenders on Indian R&D scene. It has taken different approach compared to other firms by focusing on biotechnology R&D, selecting only anti-infective segments as research focus area and putting much less emphasis on R&D collaborations for developing capabilities in innovative R&D.

7.5 Nicholas – Piramal India Pvt Ltd (NPIL)

In 2003 Nicholas Piramal India Limited (NPIL) emerged as 4th largest Indian pharmaceutical firm with sales of Rs. 12690 million and 4.4 % market share. In Indian domestic market it is leader in the cardio vascular segment and also has a strong presence in respiratory, pain management, neuropsychiatry and anti diabetics segments. NPIL's aim is to be an integrated pharmaceutical company with a commitment to discovery, development, manufacture and marketing of indigenous pharmaceutical products. NPIL is part of the Piramal Enterprises, one of the India's largest diversified business groups with interest in retailing, textiles, auto components and engineering. In 2000, the group consisted of 26 companies (including joint ventures), with aggregate revenues of about Rs. 20 billion, however in recent decade pharmaceutical business has emerged as the fastest growing and most profitable of the lot.

The Piramal enterprise was founded in 1933 and until 1987 most of the group's revenues had come from textile business, but with increasing uncertainties in textile sector, the Piramal group felt the need to diversify and in 1984 it acquired a small glass company, Gujrat Glass which supplied bottles and vials to the pharmaceutical industry. This was the first indirect contact group had with pharmaceutical business. But in 1988 group went ahead and acquired Nicholas Laboratories, an Indian subsidiary of a UK based pharmaceutical firm, renamed it Nicholas Piramal India limited (NPIL) and made it profitable in 4 years. In 1991 and 1992, NPIL commissioned two manufacturing plants at Pithampur, India.

The success of this acquisition spurred Piramal group to use acquisitions as a strategy of growth and started era of acquisitions at NPIL; company then acquired Roche products (India) Ltd in 1993, Sumitra pharmaceuticals and Chemicals in 1995, Boehringer Mannheim India Ltd in 1997. In April 1997 these three companies merged with Nicholas Piramal and a new management team was set up to manage it. This initial acquisition spree was followed by two more acquisitions – Rhone Poulenc (India) in 2000 and ICI (India) pharmaceuticals in 2002. In Dec, 2003 NPIL bought the 50% stake in Sarabhai pharmaceuticals ltd. Since most of the sellers were MNC pharmaceutical firms who wanted to quit the Indian market, NPIL acquired these firms at attractive prices and quickly synergised skills resulting into the mutual benefits. Managing Director of NPIL explain the business strategy in using acquisition as a route to growth,

"look at it from our side; we knew that with TRIPS rules being introduced sometime in future, we should need access new products. Also size matters – we needed critical mass to leverage on marketing and distribution as well as to increase the utilisation of Pithampur manufacturing plant" (Annual Report, 2003).

These acquisitions also helped NPIL in creating linkages with MNC pharmaceutical firms. Over the last sixteen years, NPIL has established a strong track record of working closely with global innovating companies and has developed an impressive record in managing business partnerships (JVs and alliances). NPIL have good business relationship with a number of multinational firms like Roche, Boehringer, Allergan, Boots, Aventis, Novartis. As a result NPIL has established a good position to become a partner of choice for any MNC looking at the Indian market. Building on these relationships NPIL has developed 2 stream approach for post 2005 scenario. The first stream includes the inward co-licensing deals with foreign firms, custom synthesis and contract manufacturing for MNC pharmaceutical firms while the second stream involves the development of the product patented molecules to make pharmaceutical drugs.

7.5.1 The contract research strategy

Based on this strategy, NPIL has decided not to follow the route of other large Indian companies of going into US markets with generics products. NPIL wants to become an ally of overseas pharmaceutical companies and therefore its main focus areas are custom synthesis and contract manufacturing instead of generic markets in advance countries.

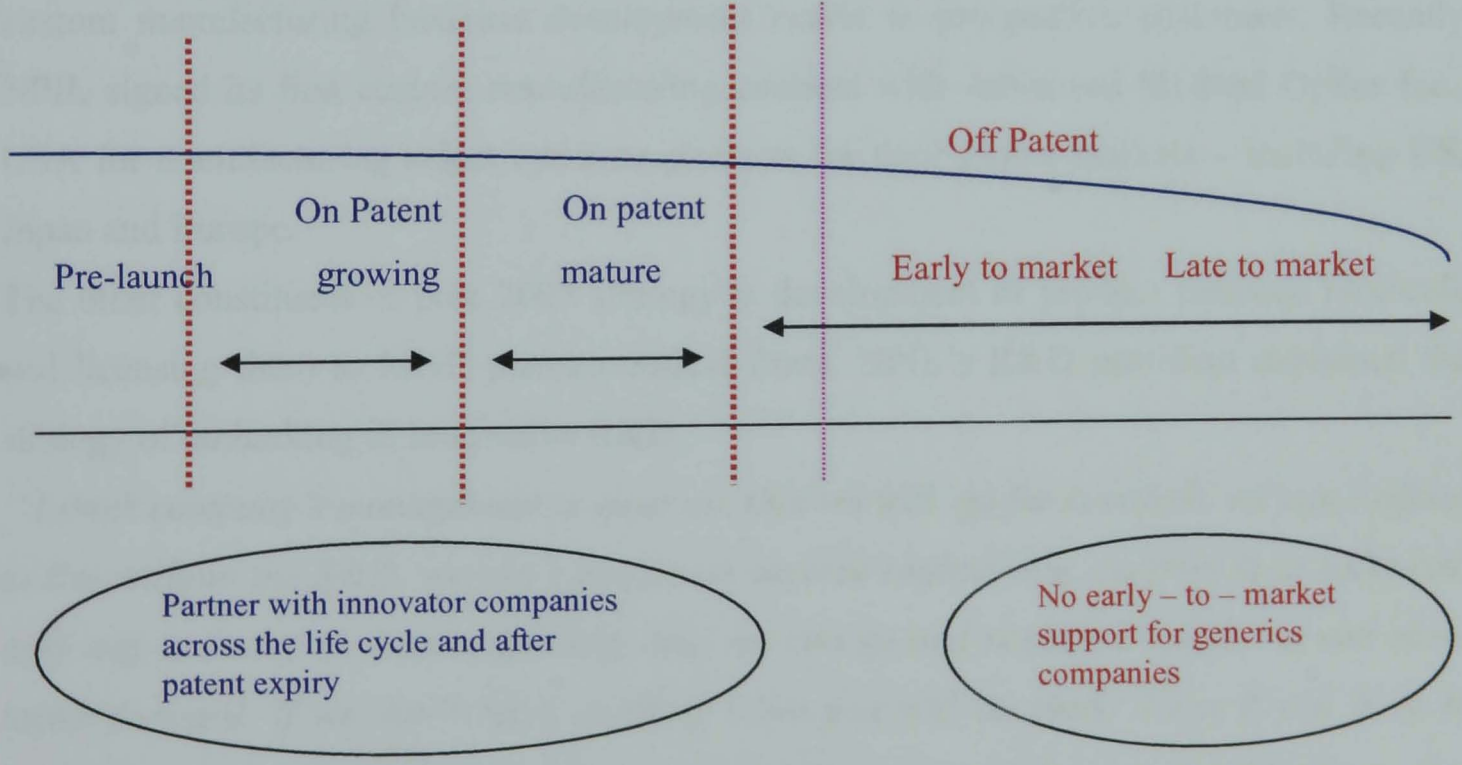


Fig7.4 NPIL partnership strategy (Annual Report, 2003-04)

NPIL strategic alliance director describes,

"I think Nicholas is a very unusual company because it has a core philosophy that partnerships prosper and it has a big track record of partnerships with companies like Hoffman la Roche, Aventis, of a whole lot of companies. So this is our core philosophy and

because of partnership two things happen, we learn a lot and also sometimes we give a lot, innovative ideas, ways of working which is different. So it's a sort of two way exchange and even in the R&D collaborations we do all the time exactly on same line".

NPIL strategy involves partnering with innovator companies worldwide across different segments of the pharmaceutical value chain (Fig. 7.4). It has developed ability to provide end to end solutions in terms of chemical synthesis of APIs through to intermediates including dosage formulations. NPIL therefore is seeking partnership with small research companies, MNC pharmaceutical firms, and generic companies in areas of manufacturing active pharmaceutical ingredient, development cheap production processes and new formulations. However, NPIL will not provide support to 'early to market' generic product development or contract with generics companies for such work. This way NPIL will be able to avoid the generic patent challenge game and maintain good relationships with MNC pharmaceutical firms. Therefore NPIL will exclusively concentrate in the 'late-to-market' generics space, as that does not conflict with NPIL's chosen business model. The 'early to market' generics involves challenges to existing patent and so patent litigation with patent holding firm whereas in case 'late to market' generics, patent is already expired and therefore involves no patent litigations.

In 2003 NPIL set up a subsidiary in the US, NPIL Pharmaceutical Inc., for moving the custom manufacturing business development nearer to prospective customers. Recently NPIL signed its first custom manufacturing contract with Advanced Medical Optics Inc., USA for manufacturing select eye care products for their global markets – including US, Japan and Europe.

The other constituent of post 2005 strategy is development of product patented molecule and licensing them to MNC pharmaceutical firms. NPIL's R&D president explained the strategy of embarking in innovative R&D,

"I think company's management is clear cut that we will go for research, we can't afford to live without the R&D, we can't just go on reverse engineering, survival is at stake and only way is that if we have something new, we can go and negotiate better, we can move better forward. If we don't have anything what you will do then? Even if you have to license-in, somebody will see what you have. So for give and take, you should able to give something, otherwise you will be on loosing side all the time".

7.5.2 Research and development

The innovative R&D forms an important constituent of NPIL post 2005 strategy. It is based on the idea of developing of the product patented molecules till Phase II and then licensing it to the MNC firms. According to NPIL's R&D president,

"the concept of discovering a drug molecule and developing it to a particular stage and licensing out or collaborating with a bigger group is the right way. The strategy is perfectly fine as we do not have the strength to do it all by ourselves".

With this aim in 1998 NPIL forayed into innovative R&D by acquiring the research centre of Hoechst Marion Russell located in Mumbai, India.

The Hoechst research centre is one of the oldest research centres in India exclusively working on drug discovery. It has been in existent from 1972 and from its inception the research centre focused on new drug discovery research and herbal research. The scientists working at this facility have many years of experience in NCEs and international filing. This research centre, now renamed as Quest Institute of Life Sciences (QILS), is guiding the NPIL's efforts in innovative R&D. QILS R&D president described activities at the research centre from the beginning as,

"we have this from 1972, we are doing basic research, there was never been reverse engineering, no iota has been done here. So for us, this is not something new, may be for others. From the day I joined; I joined in 1975 and this was drug discovery research centre. So for us discovery area is from beginning and probably may be we are adding things, we are expanding thrust, but this is not a new concept to us".

The Herbal drug research unit at QUILS focused on developing standardised, clinically proven and safe herbal products for therapeutic and cosmetic use. The acquired research centre continued with new drug discovery programs; the focus has not changed, but has only been modified to suit the NPIL.

Analogues research is NPIL's chosen research strategy in innovative R&D. QUIL's R&D president argues,

"for us, new chemical entities (NCEs) can come through modifying known molecules to get newer derivatives and developing them. It is not a sin to improve on an existing drug or some newly discovered molecule. Even big MNCs are following this concept. So the combination of having more modern type of research, trying to improve on existing products and strengthening our traditional medicines may be right strategy for India, rather than going all the way on to the ultra modern for whose sustenance we do not have financial strength".

NPIL's R&D is divided into four strategic business unit's (SBU) - Basic research (focusing on drug discovery); Natural products research (focusing on developing safe herbal products); clinical research (focusing on providing quality clinical and bio-analytical

support) and Genomics Research. These SBUs are run by different cross disciplinary teams that enable effective project management and a sharing of skills.

The focus of the basic research is the development of new chemical entities in select therapeutic areas. NPIL has narrowed down four therapeutic areas: Oncology, Diabetes, Anti Fungal and Rheumatology for its new drug discovery research (Table 7.15).

Table 7.15 NPIL's NCE pipeline (Annual Report, 2003)

NCE pipeline				
	Preclinical	**Phase I**	**Phase II**	**Phase III**
Oncology		**NP102**		
Diabetes				
Anti Fungal				
Rheumatology				

All the lead molecules in these areas are in the preclinical stage. In 2000 NPIL had filed for investigational new drug (IND) application to US FDA as well as Indian patent authorities for an anti cancer molecule NP102 (table 7.15).

In few years NPIL has built a dedicated team of scientists with expertise in medicinal chemistry, biological science, analytics and pharmacology and hired international consultant to guide company's effort in drug discovery research. From 2000 NPIL started creating a critical mass of scientists with expertise in various areas of pharmaceutical R&D (table 7.16). NPIL R&D president explained the process of establishing the innovative R&D,

"you have somebody who is a senior person and who has a good idea about how the whole thing is run. Then he fills the gap by hiring the people in these areas and getting the instruments or putting the infrastructure together. It is like a good architect who has a good idea about what he wants and he knows very clearly which contractor good for furniture, what to do, its absolutely same concepts in drug discovery".

In 2002 NPIL hired Dr. Somesh Sharma as chief scientific officer to lead innovative R&D effort. He was the vice president of Monoclonal Antibody and Vaccine Unit at Anosys Inc. US. Dr. Sharma was in the USA from 1967 where he obtained a Doctorate in Pathology from the University of Maryland's School of Medicine. He has co-founded companies like Anergen, Wizard Laboratories, S2 Pharmaceuticals and Calyx Therapeutics.

In 2004.NPIL hired Dr. Maneesh Nerurkar from Merck as head of formulations and new drug delivery systems to strengthen company's new drug delivery efforts.

Table 7.16 NPIL R&D strength (Source: Annual report, 2003-04)

Year	Total number of people	No. of people in R&D
2000-01	3600	96
2001-02	3840	130
2002-03	4036	183
2003-04	5880	255

NPIL's strategic alliance director explained the rationale behind hiring the Indian scientists working overseas in areas of innovative R&D,

"for reasons like one is that they have the ability, they can make the difference to field and second is with same amount of money here, you can get much more work done. See if you have 'thinker' who is very good and comes back and then 'doers' are all here. So you can build the team around that person. And with US $1MN we can get like 50 scientist and there you can get 10, I mean just equivalent, not exactly. So I am just saying that for same amount of money you can get the biggest bag of talent here in India".

Over the years NPIL is gradually increasing the R&D investment and are adding new resources for innovative R&D (Table 7.17). However compare to NPIL's major Indian competitor its R&D intensity is much smaller. Realising this NPIL is planning to invest Rs. 750 million over the next two years and Rs. 400 million per annum subsequently as a part of the expansion for the R&D centre. It is developing a new R&D facility in Gurgaon, Mumbai to house the planned R&D expansion. This new facility is three times the size of current facility and with that NPIL is looking to increase its scientific base by almost four times. The new R&D facility will focus on new chemical entities (NCEs) and new drug delivery systems (NDDS) in the areas of Rheumatology and cancer research. NPIL is also starting a new research centre in Chennai with initial staff strength of 50 scientists. This R&D centre will concentrate on process chemistry and stability testing specially for the export business of NPIL.

Table 7.17 NPIL's R&D intensity (Source: Annual Reports, 2000-04)

Year	R&D intensity	R&D investments (Rs Million)
2000-01	1.80	102
2001-02	2.16	204
2002-03	1.63	168.5
2003-04	3.9	301.9

In 2002 NPIL established clinical research organisation (CRO), Wellquest to strengthen its clinical trial capabilities. Aligned with NPIL's core philosophy of partnership, the aim of Wellquest is to serve the generic pharmaceutical industry by conducting clinical pharmacokinetic studies and subsequently, leveraging its skills by partnering with Indian as well as MNC pharmaceutical companies. Wellquest has state of art facilities in terms of infrastructure and GCP/GLP systems.

The major area of concern for NPIL is lack of capabilities in biological science. According to NPIL's strategic alliance director Indian pharmaceutical R&D have strong capabilities in organic chemistry or synthetic chemistry but capabilities in biology are much less. To fill that gap NPIL has established a subsidiary Genequest; a research unit totally dedicated to the study and advancement of genomics, pharmaco-genomics and bioinformatics. Genequest has been positioned as a gene discovery and database company and its key focus is to translate cutting-edge research into innovative applications. NPIL has also developed a natural products resource library of over 18,000 strains and 6,000 plants. Currently, in natural products research, NPIL has programme in fields of musculoskeletal disorders, particularly inflammatory disorders, diabetes, hepatotoxicity and antioxidants.

The other approach taken by the NPIL to fill the gap of biological capability is to hire Indian scientists working overseas in area of biological sciences. NPIL strategic alliance director suggests,

"but you can build it, not very difficult to build if there is cross border migration. We are hiring all our top molecular biologist from US. So we can build it".

In QILS almost 20-25% of scientists have experience of working abroad. According NPIL R&D president, key to attracting best research talent is to have a proper working atmosphere. He explained,

"I have a very good experience that if you give a proper working atmosphere to a scientific person, there would be quite a few wanting to come back from overseas. But once they come back you have to encourage them. Money is not the only attraction. I had people from the best universities in United States like Harvard and MIT. We may not be the best paymaster in the country. Yet what people are looking at is a place to put their talents in a proper research set up".

To establish 'proper' research setup, NPIL is involving external consultants as reviewers of the projects and which also gives NPIL scientists an opportunity to interact with reputed international scientists. It has set up a system of continuous external evaluation as well as project specific advice by availing the services of external consultant from abroad. In 2002 research scientist Dr. William Jenkins joined the board of NPIL. Dr. Jenkins will advise the company on ongoing R&D programmes, which will include audit of existing projects, the evaluation of new projects, and regulatory matters. NPIL is also taking help of Mehta Partners, renowned pharmaceutical consultants to evaluate systems and processes in research. In 2003 NPIL invited Sir Ravinder Maini and Prof. Bob Chaudhari to join the scientific advisory board. Sir Ravinder Maini, received the Lasker award in 2003 for pioneering radically new and better treatments for rheumatoid arthritis while Prof. Chaudhari has research interest in molecular basis of cancer and neuro-degenerative diseases and have a experience as senior research manager with Novartis. In 2004 NPIL appointed Dr. Saran Narang, world's renowned molecular biologists, to its scientific advisory board. Dr. Narang has been the principle research officer in Genetic Research Programme at the National Research Council of Canada since 1981. At NPIL Dr. Narang will work on the current cancer research programme.

NPIL aims to gain significant insights into new drug discovery technology from these scientists' contribution to its innovative R&D programmes.

NPIL is also encouraging its scientists to present the findings at various conferences around the world. Recently NPIL presented findings on novel anti- cancer compound at conference on molecular targets and cancer therapeutics in Boston, US. This conference was organised by American Association for Cancer Research (AACR) jointly with National Cancer Institute (NCI) and the European Organisation for research and treatment of Cancer.

7.5.3 Strategic R&D alliances

NPIL has been involved in many R&D collaborations with premier Indian research institutes like Centre of Integrated Biology, Central Drug Research Institute of India (CDRI), Regional Research Laboratory. NPIL has established new department, Strategic

Alliance Unit to scout for the collaborations and alliances in R&D as well as other areas like marketing and IT technology.
The QUIL R&D president explains,

"The CSIR labs we are collaborating with. We are also looking that any body else have any special expertise in academia. There are genuine experts, it's not that; I think there are some experts who call themselves expert but there are really genuine experts especially in CSIR labs. Some of very bright minds are there, so it just matter of knowing how to put the two organisations together and getting things done".

While collaborating with R&D institutes NPIL is more focused on areas related to biological science. According to NPIL R&D president biotechnology area is of vital importance for drug discovery and in India the biological talents and prowess in molecular biology are mainly concentrated in universities and research institutions rather than companies as most Indian companies are traditionally focused on organic and synthetic chemistry. To fill knowledge gap in biotechnology, in 2003 NPIL has signed an agreement with Centre of Biotechnology (CBT) at Anna University for exclusive R&D collaborations in areas of cancer and inflammation. The collaboration mainly focuses on identification and development of plant extracts in the repository of CBT for the treatment of rheumatoid arthritis and cancer. Dr. Balakrishanan Director CBT is head of the collaboration in close association with Dr. Somesh Sharma, Chief Scientific officer at NPIL.
NPIL's other area of focus in R&D collaboration is the identification and evaluation of new chemical entities. NPIL has entered into a contract arrangement with Indian research institutes to expedite continuous evaluation of new chemical entities (NCEs). In 2004 NPIL entered into research collaboration with the Indian Institute of Sciences (IISc) Bangalore to identify new targets to treat fungal infections. Dr. Sadhale of department of microbiology and cell biology at IISc will head the collaborative effort and NPIL will have exclusive rights to commercialise any products coming out of this collaboration. NPIL already has vast collection of natural products (over 6000 plant extracts and 18,000 microbial strains), which will also be evaluated during this period. NPIL strategic alliance director describe the working relationship,
"they (scientists from CSIR labs) come at our centre in Delhi; we have two labs working jointly. Some work is done in Delhi and some work is done in Bombay, there is free flow of ideas and we also measure productivity of our labs. We are happily going back and forth".

Recently NPIL has set up offices in UK and US with an accent on R&D collaboration with scientists from UK and Canada. In 2004, NPIL entered into an alliance with Imperial College, UK to conduct research in the field of rheumatoid arthritis.

7.5.4 Summary

In the past NPIL used inorganic route (acquisitions) for developing capabilities in manufacturing and marketing pharmaceutical drugs in India. For post 2005 scenario NPIL is focusing on partnerships with MNC firms and innovative R&D as main strategies for survival and growth. Using inorganic approach of capability development NPIL acquired the Hoechst research centre to start its effort in innovative R&D. However NPIL is also investing in building innovative R&D capabilities organically by gradually increasing investments in R&D, establishing new R&D centres, hiring Indian scientists from overseas and collaborating with Indian R&D institutes.

7.6. Lupin Pharmaceuticals ltd (Lupin)

Lupin is a dominant leader in the anti-TB segment in Indian domestic market and in 2003 had 42% market share of anti-TB segment in India. Over the years, the company has diversified into cephalosporins, cardiovascular, NSAIDs, vitamins and phytomedicine in order to boost exports and improve margins. In 2003 Lupin emerged as sixth largest Indian pharmaceutical company with a turnover of Rs. 12,327 million. Lupin export to almost more than 50 countries and 41% of Lupin's sales in 2003 came from exports; although mainly in the form of bulk drugs or active pharmaceutical ingredients to semi regulated markets.

Dr. D B Gupta started Lupin pharmaceuticals Ltd in 1968 and made Lupin a public limited company in 1987. The company had an Initial Public Offering (IPO) of Rs1865.2mn in 1993. In 2003 promoters of Lupin divested 25.1 % of its stake in favour of other investors in order to restructure its debt.

In 1972 the Lupin set up its first manufacturing unit. Now among all Indian pharmaceutical companies Lupin has the largest number of plants approved by the USFDA and UKMCA; 9 out of its 10 plants have USFDA approval. It has manufacturing plants at 3 locations in India, most of which are of global scale. Recently Lupin has set up a new plant for manufacturing lovastatin, cholesterol lowering active pharmaceutical ingredient, (API) and the company is building a new plant at Goa, India to manufacture non-cephalosporin oral finished dosages.

In the past Lupin derived a considerable portion of its revenues from producing bulk and intermediate with cheaper processes for drugs, which were bound by product patents in more developed countries. Due its skill and focus Lupin has emerged as the largest producer of anti-TB drugs Ethambutol and Rifampician in the world. In India Lupin achieved major success in the anti-TB segment with its strategy of bundling four essential TB drugs into a single dosage pack as AKT-4 kit. Doctors' preferred the AKT-4 kit as this bundling helped in preventing the selective discontinuation of medicine by patients and either resultant relapse or drug resistance. On the basis of this marketing strategy Lupin gain 60% share of Anti-TB market in India.

7.6.1 The generics strategy

For post 2005 era, Lupin's focus is on increasing sales of value added products in high margin advanced markets and exploration of new chemical entities (NCE) research through innovative R&D. Like other Indian pharmaceutical firms. Lupin has built some strengths like process R&D capabilities, internationally approved plants and regulatory competence to file ANDA application in US (table 7.18). Lupin's post 2005 strategy

involves building on these capabilities to enter generic markets in advanced countries and develop innovative product through indigenous R&D as a way to secure survival and success in product patent regime. In advance market Lupin's strategy is to build manufacturing and marketing alliances with strong international players. Lupin has established a wholly owned subsidiary in the US to identify and pursue alliance opportunities. In 2003 it signed contract with Apotex for supply of API. Apotex is a one of the largest generic focused pharmaceutical firm operating in US and Canadian markets. In 2003 Lupin received FDA approval to launch cefuroxime axetil tablets in the US generic market. Following on that Lupin formed an alliance with Watson Pharmaceuticals, a leading US generics company, as a marketing partner in the US for cefuroxime axetil tablets.

Table: 7.18 Lupin's generic product filing (Source: Annual Reports, 2003)

Year	DMF	ANDA
2002-03		
2003-04	12	5
Total	12	5

In first quarter of 2004-05, the company entered into an agreement with Baxter Health Care Corporation, a global medical products company, for exclusively marketing its generic version of ceftriaxone sterile vials in the US.

7.6.2 Research and Development

In 2001 Lupin decided to engage in innovative R&D and built a state of the art R&D laboratory in Pune, India. Lupin is a new entrant to innovative pharmaceutical research which is reflected in small but increasing R&D intensity (Fig.7.19). Lupin hired Dr. Himadri Sen as executive vice president of pharmaceutical R&D and Dr. Sudershan Arora as executive vice president, from Ranbaxy's new drug research team to lead company's effort in innovative R&D. In Ranbaxy Dr. Sen was in-charge in NDDS (new drug delivery research) while Dr. Arora was in-charge of new chemical entity research.

Table 7.19 Lupin' R&D intensity (Source: Annual Report, 2003)

Year	R&D intensity	R&D investments (Rs. Million)
2001-02	2.41	231.4
2002-03	2.30	256.5
2003-04	3.09	459.9

The hiring of these scientists proved instrumental in building the core team with expertise in drug discovery as other scientists working with them in Ranbaxy also joined Lupin. From 2001 number of scientists working in Lupin is consistently increasing (table 7.20). Lupin's vice president, NCE explain

"since I came to Lupin, things have changed because people know what I demand from them, what I am looking for a particular project. Because most people who are in Lupin, they came from Ranbaxy so they know the culture there and then they are here now".

Table 7.20 Lupin's R&D employee strength (Source: Annual Report, 2003)

Year	Total number of people	No. of people in R&D
2001-02		150
2002-03	3300	180
2003-04	3600	220

Lupin is focusing on herbal research as a source of new molecules. According to Lupin's R&D president the route of herbal medicine with established proof of concept is good one as there is still lot of knowledge untapped in these areas and if company can establish the mechanisms of action in scientific way then these molecules could be patented and marketed all over the world. In two years of starting innovative R&D, Lupin has made significant advances in its anti-psoriasis and anti-migraine programme, both being herbal based research initiatives (table 7.21). The anti-psoriasis compound (LL4218) received an INDA (Investigational new drug application) approval in April 2004 and has entered phase I clinical trials while the anti-migraine compound is in multi-centric phase II clinical trials. In case of anti-psoriatic, the chemical characterisation of the active compound, LL4218

was completed with promising activity in in-vitro and in-vivo experimental models of psoriasis.

Table 7.21 Lupin's NCE pipeline

NCE pipeline				
	Preclinical	**Phase I**	**Phase II**	**Phase**
Anti Migraine			**LL-3348**	
Psoriasis		**LL4218**		
Anti - TB	**LL-4858**			

The company is also working on an anti-TB molecule, LL 4858 and is expecting to file an IND application in 2004-05. The molecule LL 4858, a new novel anti-TB combination has found to be possessing excellent anti-tuberculosis activity.

The important part of Lupin's innovative R&D project management is creating interactions between various disciplinary teams involved with the project. According to head of NCE research, group meetings are used for facilitating the information flow across different disciplinary groups. He explained,

"I think our group meetings take care of that. I talk to my group leaders on a daily basis and then we have group meetings here; once every week for different projects where each and every chemist, pharmacologist and toxicologist has to participate there. What they have done and what they are planning to do next week so that's what we discuss here. So that way culture is changing now, they are busy working now when the system is in place".

Lupin has set up extensive mechanisms for internal as well as external reviews. For external review the company has appointed a team of senior scientists. These scientists visit Lupin R&D laboratory 2-3 times a year and review the progress of each R&D project. Lupin is also investing in the scientists by encouraging them to publish and attend various international scientific conferences. The company also invites reputed scientists at its R&D laboratory and organises workshops for its R&D staff.

7.6.3 Strategic R&D alliances

Among all the innovative Indian firms, Lupin has built strongest linkages and collaborations with Indian research institutes Lupin is actively pursuing collaborative research programmes with leading Indian research institutes like Indian Institute of

Science, National Chemical Laboratory to obtain the lead molecules. These research programmes has received funding from CSIR (Council of Scientific and Industrial Research) under the New Millennium India Technology Leadership Programme (NMITLI). NMILTI programme is launched by Indian government's Department of Science and Technology to increase the collaboration between Indian industry and government research establishments.

In case of psoriasis and TB research projects CSIR spent Rs. 90 million while Lupin has invested Rs. 250 million. The company have two partners in these projects – the Central Drug Research Institute (CDRI) and National Institute of Pharmaceutical Education and Research (NIPER). These projects involved screening of large libraries of chemical compounds available at National Chemical Laboratory (NCL), Indian Institute of Chemical Technology (IICT) and CDRI.

These collaborations are aiding Lupin in bridging the infrastructural and capability gaps in its R&D.

7.6.4 Summary

Lupin is a new entrant to innovative R&D among Indian pharmaceutical industry. The company is moving from presence in developing markets to advanced markets and transforming its R&D capabilities from imitative process research to innovative areas of pharmaceutical research like generics and new chemical entity research. Lupin is developing innovative R&D capabilities by hiring senior scientists working in other Indian firms and collaborating with Indian research institutes and universities.

7.7 Glemark pharmaceuticals ltd (Glenmark)

Glenmark is a one of the India's fastest growing pharmaceutical firm, with a major presence in dermatology therapeutic segment in Indian domestic market. It was incorporated in 1977 with initial investment of Rs.1 million and by 2003 it has grown to record a turnover of Rs.3860 million. Glenmark is ranked among the top 25 Indian pharmaceutical firms and market its products to over 50 countries across the globe.

Glenmark set up its operation distribution network first and then started investing in manufacturing facility. In 1983, the company established its first manufacturing unit in Nashik, for producing formulation products like ointments, lotions, creams and powders. In 2003 the company commissioned other formulation production facility in Goa. Glenmark also has three plants operating for its active pharmaceutical ingredient (API) business. One of them is a manufacturing plant of Glaxo acquired by Glenmark in 2002 to start regulated market business. Glenmark made this manufacturing plant USFDA compliant in two years. Glenmark is currently developing two more sites at Kurkumbh and Solapur to serve Indian and semi regulated bulk drug markets.

Glenmark's post 2005 strategy revolves around four strategic markets; domestic market, potential licensing opportunities emerging from innovative R&D, international API market and generic market in advanced countries. The core part of the strategy is developing new chemical entities for licensing alliances with MNCs pharmaceutical firms for clinical development, partnering with global generic companies as a supplier of active pharmaceutical ingredients and establishing a global distribution network for marketing generics and patented technologies. In 1999 Glenmark launched maiden public issue to fund infrastructure development for its post 2005 strategic objectives. The funds raised through public issue were invested in setting up a state of art R&D centre and development of US FDA compliant manufacturing facility and supportive distribution and marketing infrastructure in the US.

7.7.1 The generics strategy

In 2003-04 international business contributed 12.3 % to Glenmark's total revenues and showed strong growth in export of API and formulations products to semi regulated markets. It has established 6 marketing subsidiaries and expanded its operations to 59 semi regulated country markets. However, consistent with post 2005 scenario Glenmark is seriously looking at opportunities to enter the generic markets in highly regulated advanced countries like US and Europe. Glenmark's aim is to target Europe and US for generics market through ANDA filings for products which are going off-patent. In 2003 company

filed 4 DMF with USFDA (table 7.22) and set up a wholly owned subsidiary in US to augment its presence in American market.

Table: 7.22 Glenmark's product portfolio

Year	DMF	ANDA
2002-03		
2003-04	4	
Total	4	

Glenmark's advance market strategy involves conducting the primary process R&D and manufacturing activities in India and partnering with US generic companies as a supplier of API. In terms of formulation or generics market Glenmark is looking for manufacturing and marketing alliances with generic companies operating in US. Glenmark has now tied-up with three companies in North America – Apotex, Eon Labs and KV Pharmaceuticals for the supply of API. Under the agreement with KV Pharmaceuticals, Glenmark will develop eight generic products and then license them to KV Pharmaceuticals for regulatory approval and marketing in the US generic market.

7.7.1 Research and Development

In R&D Glenmark has focused on three areas of pharmaceutical research;

a. new drug discovery research,

b. formulation and new drug delivery system research for regulated and semi regulated markets and

c. process research for bulk drugs (APIs).

Glenmark's strategy in innovative R&D is to develop promising lead candidates up to early clinical stage and then licence them to international pharmaceutical companies Glenmark's strategic planning director explains,

"you have to talk about two types of research and development; one which is probably generic oriented and other is your drug discovery R&D. In drug discovery R&D even if we have capability we don't have money or the resources to go beyond Phase II so you will always need a partner. To top of it all we have weakness in biology and in terms of being up to date information because most innovation is happening in the US".

Glenmark initiated discovery research in 2000 and choose Asthama, Diabetes and Obesity as focused areas for discovery research. To accelerate drug development Glenmark started investing in innovative R&D from 2000 (Table 7.23) and established two R&D centres; one in Mumbai and other one in Nashik. The R&D centre at Mumbai is dedicated to the discovery of new chemical entities and preclinical research while the other R&D centre at Nashik focuses on formulation development, new drug delivery systems and development of different dosage forms for existing products. In terms of process R&D Glenmark has set up a dedicated team of 50 scientists to work on the development of innovative process and delivery systems for the regulated/semi regulated generics and API markets. Six chemistry research labs are located at process R&D centre focusing on various aspects of innovative process development like chiral chemistry, hetero-cyclic chemistry, resolution chemistry and carbohydrate chemistry. In 2 years the strength of scientific staff in Glenmark has increased from 100 to 250 (table 7.24), reflecting commitment of the company in R&D.

Table 7.23 Glenmark's R&D intensity and investment (Source: Annual Reports, 2000-03)

Year	**R&D intensity** R&D/Sales	**R&D investments** (Rs million)
2000-01	**1.45**	**22.0**
2001-02	**3.50**	**78.1**
2002-03	**4.41**	**147.25**
2003-04	**6.52**	**248.07**

The drug discovery R&D is based in Mumbai where Glen Saldhana, Managing Director of Glenmark is directly involved in running it. The strategic planning director explains working of discovery R&D as,

"actually here it is done differently. Discovery is handled by Glen himself so he is a sitting head, and the remaining team comprises of heads from biology, chemistry, analytical, kinetics".

Glemark has hired Dr. Gopalan as Vice President of chemical research and Dr. Swaroop Kumar as Vice President of biological research to boost drug discovery R&D capabilities. Dr. Gopalan has over 15 years of drug discovery experience in India and the US while Dr. Swaroop Kumar has experience in areas of preclinical drug discovery research with Dr. Reddy's laboratories. Glenmark has built a team of scientists with diverse backgrounds and

almost 20% of R&D scientists have post-doctorate degrees from the US. A few of them also have experience of working on drug discovery in R&D's of multinational pharmaceutical firms.

Table: 7.24 Glenmark's R&D employee strength (Source: Annual Reports, 2000-03)

Year	Total number of employees	No. of R&D employees
2000-01	1800	100
2001-02	2000	150
2002-03	2500	250

In four years of starting innovative R&D programme Glenmark has come up with a number of strong lead candidates (table 7.25). In the asthma segments, Glenmark's drug candidate GRC 3886 is now set to enter Phase I clinical trials. This lead has shown impressive anti-inflammatory effects in animal models of pulmonary inflammation. In 2004 Glenmark contracted Quintiles, a leading global Contract Research Organisation (CRO), to conduct Phase I of clinical trials of its drug candidate for Asthma, GRC-3886. In case of the, anti diabetic GRC 1087, Glenmark has established proof of concept in animal studies and is waiting for approval to start clinical trials.

Table 7.25 Glenmark's NCE pipeline (Source: Annual Report, 2003)

NCE pipeline				
	Preclinical	Phase I	Phase II	Phase III
Asthma	GRC3566 GRC 3886			
Obesity	GRC 1087			
Diabetes	GRC 8087			

Like other innovative Indian pharmaceutical firms Glenmark has chosen analogue research as main research strategy for discovering new chemical entities. Glenmark's VP chemical research explained the analogue strategy.

"we don't have that much capability to go into three dimensional structure of the receptor, that's why we choose projects in such way that three dimensional picture of the

receptor is already reported. So when we choose therapeutic targets we take into account whether the three dimensional structure of the receptor is known".

Glenmark has also established a full fledged pharmacology department with modern instruments to screen new molecules. The analytical department is a central facility; it supports all R&D programmes like drug discovery, new drug delivery system research and formulation development projects. Glenmark's strategic planning director describes the working of the project as,

"we only do analogue research; we are not doing rational drug design NCE research. So actually you need active pharmacore around which everything is modelled and that would be analysed by chemists and if all of them agree that there is space and if the biologists say that mechanism will do good then we go ahead with the project".

Glenmark has also set up a scientific advisory board with internationally reputed scientists to review and advice on the research projects. The scientific advisory board includes Dr. Clive Page, Director of Pulmonary Pharmacology, King's College, UK an authority on asthma in the medical field. Dr. Jonathan Arch, Director of Metabolic Research, Buckingham University and Dr. Faizulla Kathawala, a scientific consultant are also part of Glenmark's scientific advisory board.

Glenmark is putting extensive emphasis on conference attendance and presentations. Scientists working at Glenmark research centre are encouraged to present research findings at various national and international seminars and meetings. Glenmark has already presented the findings of asthma and diabetic research in various international conferences. In 2003 Glenmark presented GRC 3566 at World Inflammatory conference while GRC 3886 is been presented at four international conferences in 2004. Glenmark is also active in publishing the results of in-house research in peer reviewed international journals.

The company has incorporated a wholly owned subsidiary in Switzerland during 2004 to undertake patent registrations in regulated markets and to set-up R&D activities. Glenmark's Swiss subsidiary will manage Glenmark's global IP (intellectual property) portfolio and coordinate clinical trials on its NCE compounds.

7.7.2 Strategic R&D alliances

Glenmark is collaborating with National Chemical Laboratory (NCL), India for research on Anti inflammation therapeutic segment. This collaboration is financially supported by department of Science and Technology's research programme; New Millennium Technology leadership initiative (NMTLI).

7.7.3 Summary

The case of Glenmark pharmaceutical presents the response by medium size Indian pharmaceutical firm to change in patent law. For post 2005 survival Glenmark is building on its process R&D capabilities to develop competencies for generic product R&D to compete in API and formulation (generic) markets of advanced countries. Importantly Glenmark is also investing heavily in R&D to develop capabilities in innovative areas of pharmaceutical research like new chemical entities and new drug delivery system.

7.8 Conclusion

This chapter presents the cases of six innovative Indian pharmaceutical firms. It described the development of organisational capabilities in each firm, specifically focusing on post 2005 strategies of firms to transform its product portfolios, markets and R&D capabilities. The description mainly discussed the processes employed by each firm to develop competencies in innovative process and product R&D.

Next chapter analyses the firm level learning processes involved in development of knowledge creation capability for innovation in firms under study. It discusses the inter-firm similarities and differences in approaches as well as intra firm intricacies involved in transformation of capabilities.

It concludes with insights on firm level process involved in development of innovative capabilities pointing out the limitations of learning hierarchy models of developments.

Chapter 8

ANALYSIS AND DISCUSSION

This chapter analyses the firm level learning processes involved in development of knowledge creation capabilities for innovation in innovative Indian pharmaceutical firms. It presents an analysis of intra firm difficulties and mechanisms involved in the transformation of capabilities and points out inter-firm similarities and differences involved in the development of innovative R&D competencies.

8.1 Introduction

The theoretical framework (Fig 8.1) discussed in chapter 4 guides the analysis of the firm level learning processes involved in the development of innovative capability. The theoretical framework is based on the absorptive capability concept and draws on the strategic management and organisational theory literature which is focused on knowledge, learning and innovation.

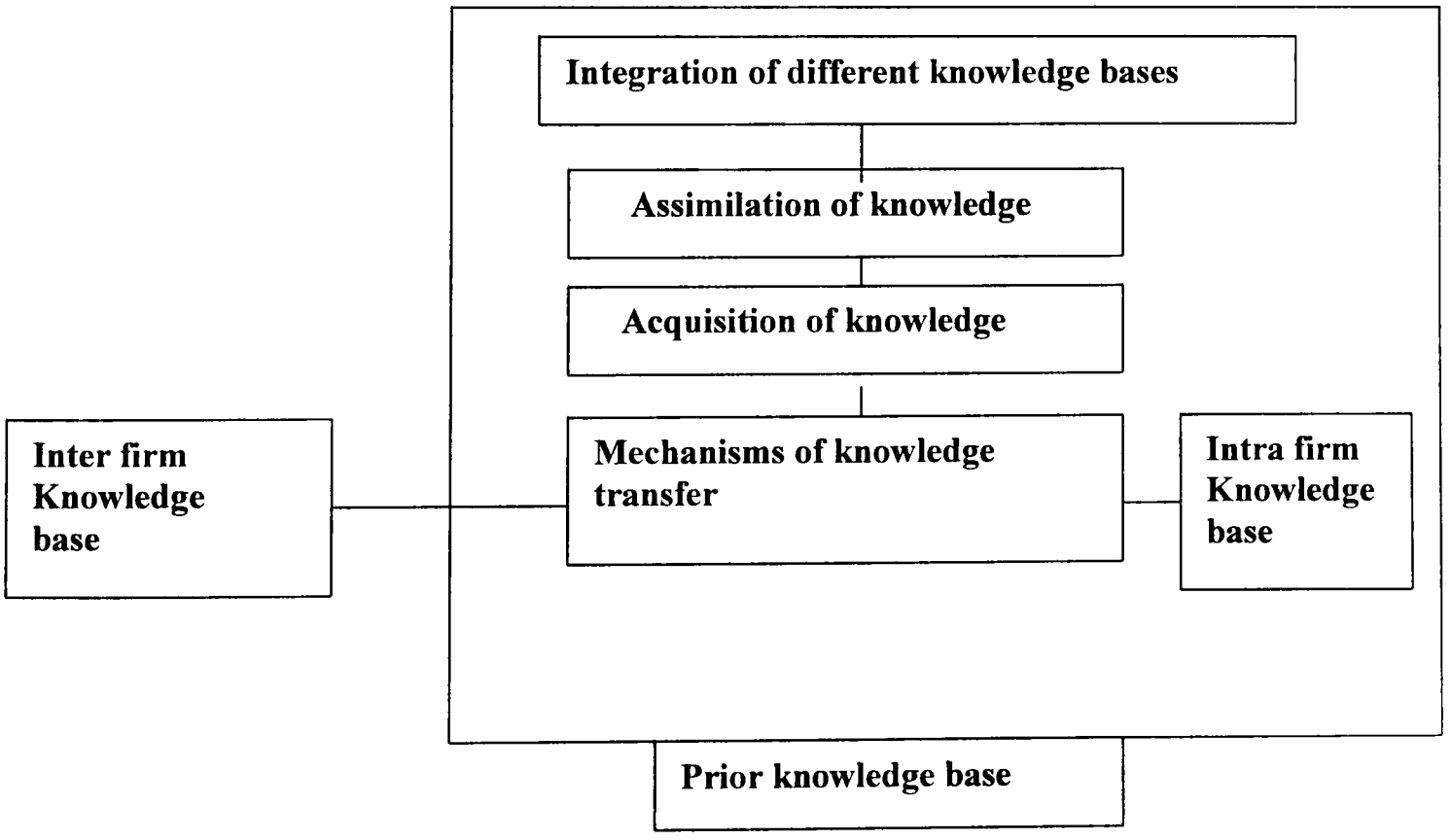


Fig 8.1 Theoretical Framework

Based on the theoretical framework the analysis presented in this chapter is focused on the transformation of capabilities in terms what happens in 'practice' as a response to change in the external environment. So the analysis covers accumulation mechanisms which

govern the content and location of stocks of knowledge in the firm; the transfer mechanisms which govern the flow between internal and external sources of knowledge. It also includes assimilation mechanisms which govern the way in which firms internalise the newly accessed knowledge and examines the application or deployment mechanisms like coordination and integration which govern the ways in which the stocks of knowledge or specialised knowledge bases are brought to bear within decision making.

To summarise, it explores the social processes or mechanisms used for knowledge acquisition, transfer, assimilation, and application in the sample firms. It also analyses the emergence and development of a prior knowledge base and its usefulness in new environment. This chapter thus focuses on the diverse set of learning processes used by Indian pharmaceutical firms and presents an analysis in terms of the differences in functioning and implementation of these processes in each firm.

The analysis will show that as a response to change in patent law innovative Indian pharmaceutical firms have moved incrementally by developing competencies in generic product R&D and simultaneously these firms have invested to build the competencies in innovative product R&D. The analysis will also reveal that at the firm level movement from imitative R&D to innovative R&D requires an 'unlearning' of those capabilities which served well in imitative R&D but may not be so relevant in innovative R&D. Therefore, an important aspect of learning in the development of innovative R&D capabilities is an unlearning of the rigidities accumulated in imitative R&D.

The analysis will suggest that learning at the firm level is neither a linear nor a automatic process and requires a deliberate learning strategy.

Section 8.2 analyses the response of the sample firms to the strengthening of patent law and maps the technological paths adopted by firms on a product- process-proprietary grid. Section 8.3 discusses the difficulties involved in moving from a imitative pharmaceutical R&D to innovative product R&D capabilities. Section 8.4 presents learning processes involved in the development of innovative product R&D capabilities in the firms under study. Section 8.5 describes the inter-firm differences in learning processes and its implication for development of innovative R&D capabilities. Section 8.6 presents the conclusions.

8.2 Technological paths of innovative Indian pharmaceutical firms

This section reflects on the paths taken by innovative Indian pharmaceutical firms' to transform their R&D capabilities in response to a strengthening of patent law.

The product/process and proprietary gird (Fig. 8.2) developed by Forbes and Wield (2002) is used for analysing the technology paths taken by Indian pharmaceutical firms in response to emerging TRIPS regime. The grid is divided into four quadrants based on product – process – proprietary dimensions and provides a framework to track the movement of firms from imitative R&D to innovative process and product R&D. Proprietary capability comes from knowledge that is distinctive to the firm. The test of proprietary knowledge is whether or not it permits the firm to add value ahead of its competitors. In some cases this proprietary capability takes the form of intellectual property formally owned by firm: patents, trademarks, designs, copyright.

In case of pharmaceuticals a 'patentable' product or process certainly allows value addition in a firm's portfolio compared with competitors and therefore in the grid the proprietary dimension for pharmaceuticals takes the form of process or product patent formally owned by the firm. In the grid capability to manufacture bulk drugs or API (active pharmaceutical ingredient) will occupy the process- non proprietary quadrant while branded formulations will represent the product non proprietary quadrant. The manufacturing of active pharmaceutical ingredient is basic ability to produce the drug in powder or raw form while the branded formulation involves preparing the drug in different dosage forms. Generic drugs in advanced markets like the US and Europe represents process – proprietary grid and new chemical entities or new drug delivery systems will occupy the product proprietary quadrant. Generic R&D involves the development of product with non-infringing and novel 'patentable' process and which allows firm to add value in comparison to competitors. The new chemical entity involves the ability of the firm to conduct research and develop innovative patentable drugs in form of new therapies or improvement in current therapies as a cure for diseases while new drug delivery system (NDDS) involves the development of technology to introduce a drug at the diseased site in a novel way.

The innovative Indian pharmaceutical firms began by manufacturing bulk drugs and then followed it by developing capabilities to produce and market branded formulations for the domestic market (quadrant I and II). In terms of capability development this represents a move from process-non proprietary quadrant to product non-proprietary quadrant, represented by vector A in fig 8.2.

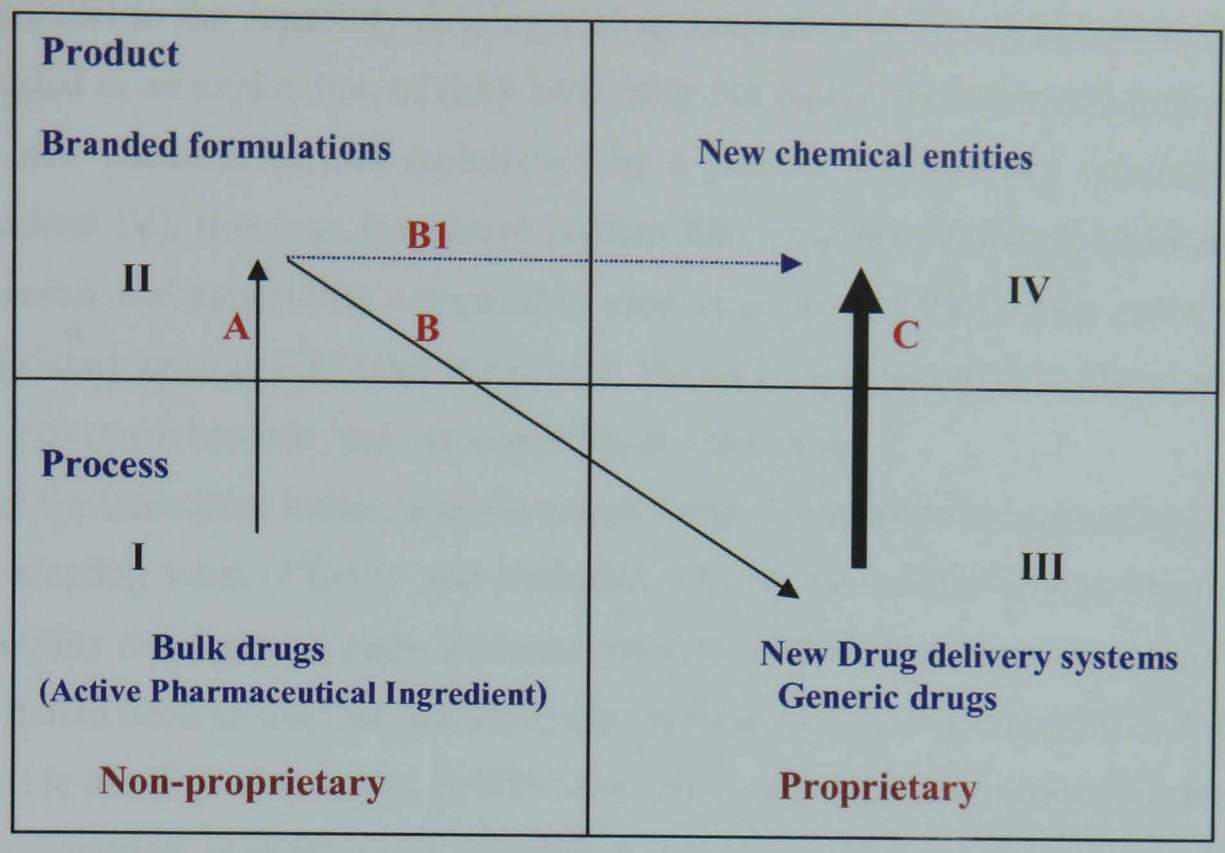


Fig.8.2 Proprietary- product –process grid (Ref: Forbes and Wield, 2002)

Generic product R&D which occupies process-proprietary quadrant (quadrant III) involves creating non infringing processes or in some cases invalidation of an existing patent. The non-infringing process provide the product a novel and innovative element and firms could apply for a patent for this new process. In case of innovative Indian pharmaceutical firms the development of innovative processes to create generic version of existing drugs forms the incremental capability development represented by vector B in fig 8.2. The knowledge base underlying generic product R&D builds on organic and synthetic chemistry skills accumulated in reverse engineering but adds a patentable innovative element, providing value for the firm in comparison with its competitors. This represents process – proprietary quadrant (III) and shown by examples like Ranbaxy's process for preparing Cefaclor or DRL's development of Fluoxentine 40 mg capsules and subsequent 180 day exclusivity for in US generic market. Both were the patentable innovative and novel processes for known products and created the value for these firms over their competitors. Indian firms developed generic product R&D competencies by building on strong synthetic and organic chemistry skills and leveraging process R&D capabilities. This innovative process R&D not only helped these firms to build capabilities in different aspects of regulatory management such as strategic patenting of innovations and patent litigation but also developed the capabilities required to compete in highly competitive generics market of the US and Europe. Therefore movement towards innovative process R&D is exploitative in nature and represents incremental capability development.

In parallel to the capability development in innovative process R&D, these Indian firms' invested in an exploration of risky and costly but highly profitable and innovative area of the new chemical entities represented by a product – proprietary quadrant in the grid (quadrant IV). However, innovative product R&D requires a different knowledge base and organisational capabilities compared to innovative process R&D. This movement towards proprietary product R&D (Vector B1 and Vector C) is explorative in nature and represents the movement towards 'radical' capability development.

Thus the innovative Indian pharmaceutical firms responded to strengthening of patent laws by adopting what O'Reilly and Tushman, (2004) have called ambidextrous technology capability development paths. Generics product R&D is also creating economic resources for Indian firms to fund the investment in exploration of radical capabilities. It helped these firms to develop what Teece, (1987) have called complimentary assets such as competitive manufacturing, marketing and distribution networks and the ability to deal with regularity procedures involved in getting new products to the markets in advanced countries. Thus the exploitive use of process R&D has helped these firms to develop the complimentary capabilities required to compete in new product markets.

8.3 Difficulties involved in moving from imitative R&D to innovative pharmaceutical R&D

This section presents the classification of knowledge base and respective levels of capability in process and product pharmaceutical R&D (Fig.8.3). Using this classification it reflects on the difficulties involved in moving from imitative to innovative R&D and discusses their implications for innovative R&D capability development. This classification also helps in mapping the level of innovative Indian pharmaceutical firms in terms of innovative product R&D capabilities.

In the case of pharmaceutical R&D, process and product R&D capabilities can be differentiated on the basis of the complexity of knowledge base which can be characterised as basic, intermediate and advanced levels.

Based on Bell and Pavit (1993), a basic level innovative capability is taken here as an ability to make minor adaptations to production and assimilate technology. Intermediate innovative capability refers to the ability to generate incremental technical change in product design, quality and production processes, it also includes the ability to search and evaluate external sources of technology. Advanced innovative capability refers to the ability to generate new product and process innovations. Knowledge base can be categorised as simple and complex based on the nature of technological challenges

involved in development of products and the capabilities required to develop those products.

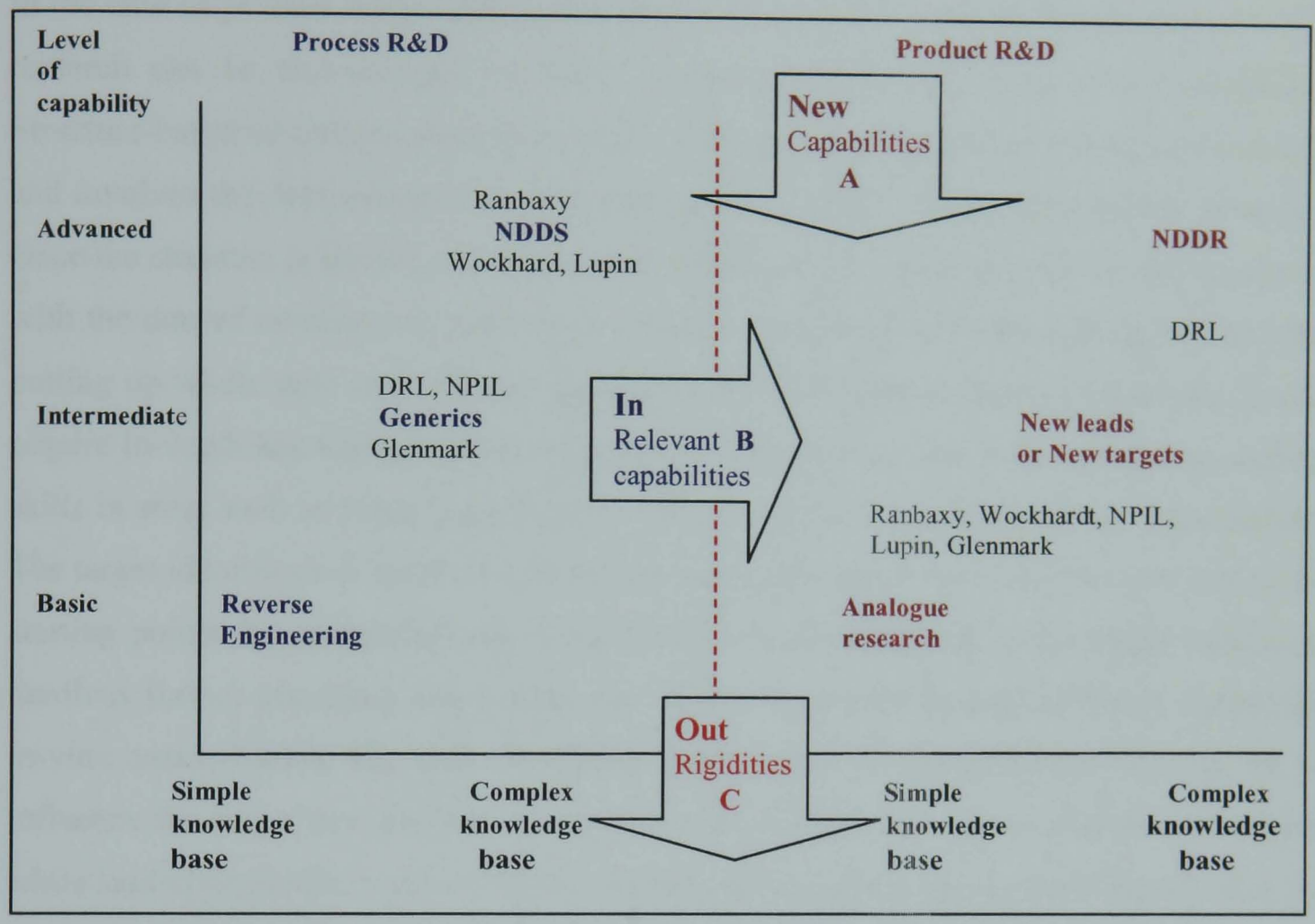


Fig.8.3 Indian pharmaceutical industry: changing skills and capabilities

In the case of process R&D, the capabilities in reverse engineering, generic R&D and new drug delivery systems are mapped as basic, intermediate and innovative. Reverse engineering involves copying the manufacturing process using indigenous sources of technology while generic R&D includes producing the product with non-infringing and innovative processes. New drug delivery systems (NDDS) involve the development of technology to introduce a drug at diseased site in a novel way. To the larger extent firms develop new drug delivery systems to

a. develop a generic product,

b. develop an improved product and

c. extend exclusivity.

In all these cases, research involves working on formulation part of already patented drug rather than research on a novel drug. It involves finding of newer and better routes of administration of proven drugs by application of modern technology for oral, nasal and other forms of drug administrations. This provides the new drug delivery system research a definitive and well defined boundary of complexities. Therefore new drug delivery

definitive and well defined boundary of complexities. Therefore new drug delivery research is a less risky and cost effective strategy, representing an advance level of capability in terms of formulation research part of the process R&D.

In the case of product R&D analogue research, new target or new leads and original NCE research can be characterised as basic, intermediate and advanced level capabilities. Structure-based or rational drug discovery is characterised as advanced level of capability and involves the determination of a disease causing protein's three-dimensional structure. Once the structure is known, novel chemical entities are designed to 'lock-in' to the protein with the aim of reversing or arresting a disease's progression. This research will involve putting up whole new and original hypotheses about the disease and its treatment. It will require in-depth knowledge about biological and chemical aspect of the disease as well as skills in areas such as target identification, validation and lead identification, optimisation. The target identification involves identifying biological targets that have the potential to be starting points for successful and commercially viable treatments while target validation involves further screening and a step-wise selection process through different functional in-vitro assays (tests). The lead identification and involves chemicals that have proven to influence the target in a way that gives them the potential to become effective treatments while lead optimisation involves further refining of lead molecules by carrying out tests for attributes such as absorption, duration of action and delivery to the target. The results of these tests determine whether the leads have the potential for testing in humans and have the qualities to become a safe and effective drug.

The intermediate capability in product R&D represented by new target or new leads requires higher skills than analogue research. Thus novelties in terms of new lead or new target will demand a deep knowledge about areas such as structure-activity relationship which involves analysing reactions between molecular structure of new chemical entity and three dimensional structure of protein.

Analogue research involves the modification of existing molecule which can provide better efficacy or reduce the side effects and add value to the therapy. This research makes the use of already discovered molecules and targets so the requirements of skills in lead optimisation or target validation are limited in it.

The analysis of the sample firms' capabilities in process and product R&D suggests that in terms of process R&D, Ranbaxy has acquired advance level capabilities in process R&D while other firms are at intermediate level. In terms of product R&D, DRL has acquired the capabilities to conduct research involving new leads or new molecules whereas other firms are at analogue research stage. This is evident by the fact that Ranbaxy developed the once- a- day new drug delivery system for Ciprofloxacin and licensed it to Bayer while

Reddy US Therapeutics, DRL's R&D subsidiary in US has filed a patent application for molecule which was the outcome of structure based drug discovery research approach.

This classification of process and product R&D capabilities assist in tracking the difficulties and mechanisms involved in the transformation of capabilities to move from imitative process R&D capability (reverse engineering R&D) to innovative process and product capabilities. The different knowledge base, organisational processes and capabilities required in imitative R&D and innovative R&D shows that firm having advance level competencies in imitative process R&D may start with little or no basic level capabilities in innovative product R&D. Innovative Indian pharmaceutical firms have developed basic level of process R&D capabilities through imitative R&D and as a response to change in patent law, they are moving towards the development of advance level process and product R&D capabilities. This movement involve the integration of existing capabilities with newly acquired knowledge but crucially it also involves the unlearning of non-relevant capabilities or rigidities. The development of product R&D capabilities will involve acquisition of new capabilities and combination of those with existing relevant capabilities (fig. 8.3 vectors A and Vectors B). It will also involve removal of capabilities which were useful in process R&D but redundant in product R&D (vector C).

The next section discusses the capabilities from process R&D which are not relevant to innovative product R&D.

8.3.1 Learning and unlearning

The analysis of the firms under study reveals that these firms will have to get rid of capabilities which are not relevant to new environment. It also suggests that these firms will have to acquire new capabilities and combine them with existing relevant capabilities to develop capabilities in innovative R&D (Table 8.1). The analysis of innovative pharmaceutical firms suggests that R&D infrastructure, complimentary manufacturing and marketing assets, linkages with research institutes and understanding about the pharmaceutical R&D are relevant capabilities in innovative R&D. In addition to that firms will have to add new knowledge in key product R&D disciplines like medicinal chemistry, biology, establish product R&D infrastructure to facilitate the development of innovative R&D capabilities and create culture of innovation in their R&D to foster the innovative R&D.

The important rigidities that have emerged are a. imitative R&D organisational routines. b. in-house nature of R&D and c. organisational mindset and these are discussed in this section.

8.3.1a Reverse engineering experienced scientists in discovery R&D

Success in imitative R&D draws on branches of chemistry like synthetic chemistry, organic chemistry and basic pharmacology. Indian pharmaceutical firms in their R&D laboratories employ organic and synthetic chemists who could reverse engineer any molecule or develop efficient and cheap processes for any patent protected molecule. However, innovative R&D is about motivating scientists to think 'out of box' or think differently in novel and creative way. For example, if there is existing anti-diabetic molecule already on the market, then developing a new molecule or identifying a new target site, which will aid in a discovering a different therapy approach to cure a disease. Lupin's head of new drug discovery explained,

"for new drug discovery you can get good chemist here but they don't have expertise of how to design molecule, how to look at receptor, how to look at molecular modelling. If you are not trained then it's difficult to understand the interactions".

Table 8.1 Rigidities, relevant capabilities and new capabilities

IN	OUT	NEW
Understanding of the pharmaceutical R&D **Complimentary technological assets**: Skills in pharmacology, analytical chemistry, process R&D (for development phase) - Sources of knowledge created through distribution, marketing routes in overseas markets **R&D Infrastructure** **Existing relationships with research institutes**	**Mindset** a. Short term vision of R&D b. Domestic market focused thinking **Reverse engineering experienced scientists in discovery R&D** **R&D management practises** a. Resource allocation b. Project review **In-house nature of R&D**	**Culture of innovation** R&D management mechanisms **Research talent** a. expertise in medicinal chemistry and biology ; b. scientists with experience in product R&D c. incentive schemes for scientists **Product R&D infrastructure** **Networking and collaboration capabilities**

The research skills required in innovative R&D differs from imitative R&D in terms of design and conduct of experiments as Ranbaxy's former R&D president elaborates,

"the organic chemist in process development lab works on or run the batches of 10 kg or 20 kg whereas in drug discovery laboratories he does the milligram jobs and this switch can be difficult".

Process R&D is about developing scale intensive manufacturing processes, so experiments involve changing solvents temperature, pressures and studying their impact on the output, safety and cost. Due to working on these parameters scientists create their own biases and ways of working which are suitable for process R&D but these become irrelevant in innovative product R&D. Lupin's head of new drug discovery explains,

"There is this scientist; he was head of one group of the generic people. So I tried this scientist for eight months in new drug discovery, he couldn't able to deliver anything to me. Finally I have to ask him to please go back to generics now. This is my personal experience, with reverse engineering experienced scientists, it is difficult".

Innovative R&D requires scientists skilled in a wide range of disciplines and scientists working in the sample firms lacked the knowledge in those of areas. Glenmark's strategic planning director explains,

"what you need is innovative chemistry so which is not same as reverse engineering. So in fact we do not prefer the people in discovery chemistry who have the experience of reverse engineering. If the scientist has done some non-infringing work or he has done some original work then we will take him but not only process development because you just can't take a good process chemist and try to make him a good medicinal chemist or a chemist who is able to deliver on an innovative chemistry or chemistry which he is not done before".

Therefore these firms have not employed process development scientists for new chemical entity research and have hired product R&D experienced scientists or fresh scientists for innovative product R&D. NPIL's R&D president suggests,

"I mean they have to break the routines, they are aware about that. So that is why they have to hire people who are not already mentally set for the routines".

8.3.1b Ways of managing R&D projects

The reverse engineering method of product development required relatively little communication of knowledge across the boundaries of the firm or across disciplines or therapeutic areas within the firm. Firms were organised R&D functionally with chemist at the heart of the process and pharmacologist working down stream. However, according to Henderson, (1994) innovative pharmaceutical R&D requires the exchange of knowledge across the boundaries of the firm and across disciplinary and therapeutic class of boundaries within the firm. Innovative R&D requires the input from various disciplinary knowledge bases and success is linked with organisational ability to integrate knowledge across disciplines. Therefore, innovative R&D requires different mechanisms to manage,

design and review research projects than imitative R&D. Lupin's head of new drug discovery suggests,

"your mind is set for reverse engineering and to transform that mind into new drug discovery you need to know lot of pharmacology, toxicology and pharmacokinetics. If you know only chemistry, you can not design the molecule. You have to look at the total pharmacology of that particular disease, then bioavailability issue, toxicology issues".

This need for integrating different disciplinary knowledge bases shows that the organisational practices and routines accumulated in imitative R&D cannot be directly applied in innovative R&D. Glenmark's strategic planning director comments,

"for innovative R&D, you need to form forum in a way that there is interaction between different departments where as reverse engineering is a individual job, one fellow sitting in the laboratory can do it. Drug discovery is completely team effort so you have to have chemist talking to biologist, biologist talking to the kinetist, kinetist and biologist talking to analytical fellow and things like that. So you need to form a forum and structure where actually these will come together".

The R&D culture developed in the imitative 'era' also represented a major obstacle in development of innovative R&D capabilities. Lupin's head of new drug discovery explains,

"people are not taking the responsibility which they should take. Its normal culture here that you tell them to do certain things then you have to after them to get things done where as in US once a person gets in project then they don't talk much. They are busy with their own work but here you have to push the people".

He elaborates further on his experience in other Indian pharmaceutical firm,

"they go on working on project which doesn't give anything for 5 years; why you want to continue with that. You must throw it away don't run over that anymore or change ways of working there. So I don't think we had any major issue there except for culture changes which we have to implement there".

The other important issue is the R&D infrastructure required for innovative R&D. The present R&D infrastructure in Indian pharmaceutical firms is adequate for process R&D research but will need up-grading for innovative product R&D projects. Innovative R&D requires the state of the art instrumentation specifically in key disciplines like chemistry and biology. The emergence of drug discovery technologies like combinatorial chemistry or high-throughput screening has transformed the drug discovery process. Wockhardt's head of pharmacology comments,

"we don't have right now the facilities which scientists working overseas have seen 10 years back. Those things they can get there or in US companies or any other research institute overseas just by signing certain things, it's not possible to get it here. We do get lot of capital budget but there is still gap between us and West".

8.3.1c Mindset

The most important issue that has emerged is mindset to shift from copying a product towards a creating and generating innovative product. Indian pharmaceutical firms have over the years gained immediate returns on R&D investment and have mostly competed in the domestic market on the basis of cheap, albeit efficient, production processes. The reverse engineering new product development requires short duration for completion of projects. Firms can get immediate return on R&D investment by introducing the product in market as imitative R&D doesn't require time consuming clinical trials. But in case of innovative product R&D the life cycle of product development is long and takes 10-15 years. So firm have to be mentally prepared to commit the resources for 8-10 years without immediate returns. The former R&D president of Ranbaxy comments,

"it is a mind set problem; those making profits don't want to invest in product R&D. The costs involved in drug discovery and development are really enormous and returns don't come fast. Most of Indian firms have this habit of getting quick returns and so if a firm wants quick return on the investment, its not going to be there".

Although the innovative firms have increased R&D investment from 1995 (Table 8.3) but there is wider consensus about need to increase it still further. One R&D vice president defends the gradual increase of R&D investment saying that 'every company needs to develop its own comfort zone of risk' and links the issue to the mindset problem. He accepts the difficulty of convincing people to make investments without any foreseeable returns for 8-10 years, and cite this as a reason for the gradual increase in R&D investment. In case of innovative Indian pharmaceutical firms, mindsets shaped by practises of getting immediate return on R&D investments, inferior technology and domestic market focused thinking has emerged as one of the main constraints to move from imitative R&D to innovative product R&D.

8.3.1d In-house nature of R&D

In the reverse engineering era Indian pharmaceutical firms built process R&D capabilities in-house as profits were totally linked to efficient and cheap production processes. The intense competition and lack of trust due to a weak regulatory environment shaped the in-house nature of R&D, resulting in a lack of collaboration between industry and academia. However, innovative R&D requires contributions from various disciplinary areas like medicinal chemistry, biology and pharmacology which are advancing at an extraordinarily rapid rate. Scientists working in innovative R&D need to be current with a wide range of specialised knowledge. The Indian pharmaceutical firms are chemistry based but biological knowledge and talent in India is concentrated in research institutes such as Indian Institute of Sciences, National Institute of Immunology, Centre for Cellular and Molecular Biology and others. Therefore, Indian pharmaceutical firms have to change the in-house view of R&D to access and acquire disciplinary knowledge bases in innovative R&D. DRF's former R&D president suggests,

"what we need to do in next 5-10 years is enhance our interaction with academia and research organisation across the world. Allow our scientists to get exposure in fast moving science laboratories".

8.3.2 Summary

The analysis points out that in the case of Indian pharmaceutical firms under study the main rigidities that have emerged are

a. imitative R&D organisational routines,

b. in-house nature of R&D and

c. organisational mindset shaped by short term vision of R&D investments and a domestic market focused approach.

The difference of knowledge base, organisational practises in imitative and innovative R&D implies that the processes and capabilities that served firms well in the past are not relevant in new regulatory and competitive environment. According to Leonard – Barton (1992) core rigidities are flip side of core capabilities and represent the gap between current environmental requirements and a firm's core capabilities. The deeply embedded knowledge system sets actively create problems and so the firm has to eliminate or minimise the impact of these rigidities. In case of Indian pharmaceutical firms it suggests that an important part of learning is 'unlearning' or forgetting past behaviours. Hedberg (1981) points out that knowledge grows and simultaneously becomes obsolete as reality changes. Understanding involves both learning new knowledge and discarding obsolete and misleading knowledge. The discarding activity – unlearning – is as important part of

understanding as adding in new knowledge and slow unlearning is a crucial weakness of many organisations in development of new capabilities. So, in case of innovative Indian pharmaceutical firms getting rid of 'rigidities' accumulated in reverse engineering era forms an important part of learning in development of innovative R&D capabilities.

To sum up, some of the processes and capabilities accumulated through imitative R&D can actively create problems in innovative R&D where projects are designed to develop new, non traditional products and capabilities. This suggests that as firms move from imitative process R&D to innovative product R&D, they will have to get rid of those capabilities which are useful in process R&D but can become rigidities in product R&D. Therefore in case of Indian pharmaceutical firms unlearning of obsolete abilities formed an important constituent in transformation of capabilities from imitative R&D to innovative product R&D.

The next section elaborates on the learning processes involved in development of innovative R&D capabilities in firms under study.

8.4 Processes involved in the development of competencies in innovative R&D

This section analyses the learning processes used by the sample firms to develop the required competencies in innovative R&D. It focuses on the key knowledge creation processes such as the mechanisms involved in acquisition of new knowledge, its assimilation, transfer and application. It also discusses relevant aspect of prior knowledge base in new environment.

8.4.1 The prior knowledge base and its relevance in innovative R&D

Prior knowledge provides the base on which firms develop capabilities to cope with technological change or a new external environment. According to Cohen and Levinthal (1990), the absorption of new knowledge depends on the accumulated stock of past capabilities or knowledge and mechanisms of knowledge transfer. The accumulated stock and content of knowledge gives firms an ability to exploit external knowledge and is therefore the critical component firms' ability to develop new capabilities.

Over the years Indian pharmaceutical firms have used reverse engineering as a mechanism for knowledge acquisition and built strong capabilities in synthetic and organic chemistry. New drug discovery research, however, requires expertise in medicinal chemistry (synthesis and natural product extraction), toxico-pathology, bio chemistry, biology in addition to clinical pharmacology. Therefore according to one pharmaceutical consultant, *"current expertise available for reverse engineering research is totally inadequate for new drug discovery research"*.

However, from the beginning of the 90s these Indian firms started innovating in process development by creating cheaper processes. These firms challenged their scientists to develop the product with alternative production processes involving less cost or develop processes which would give more yield. This created a strong knowledge base in chemistry and greatly increased expertise in pharmaceutical technologies building the foundation for innovative process and product R&D. For example, Ranbaxy's process development effort for Cefaclor involved developing a new process different from Eli Lily's patented 70 processes. This required in-depth knowledge about the complexities involved in process development as well as creative thinking.

Gradually these firms started targeting the generics market in advanced countries and which involved developing product with new non infringing processes. For example when DRL developed Pfizer's drug Prozac (Fluxotine), the company not only produced the drug with new process but also with new dosage form and as a result DRL got 180 days exclusivity in the US generics market for this innovation. Therefore, the innovation was part of not just a new process for producing the molecule but it actually renewed the product or created a new market for product; the product was same but the methodology adopted involved creativity and innovativeness. The generic product R&D showed the way of creatively building a knowledge base and gradually built a tradition of creative research in these firms. This innovative way of developing processes for production forced scientists to think differently, changing the mindset from 'imitative thinking' to 'original thinking'. NPIL's strategic alliance director comments,

"It's just the target we never focused them on. In old days we taught them chemistry and said do it. We never told them find a non-patent infringing process to make a drug which is perhaps eco-friendly whose cost is half and you can find an innovation which you can patent. We didn't tell them the goal was that so they didn't have that in their mind".

The generics product development created understanding about innovative pharmaceutical R&D and helped firms to learn about practices required to operate in advanced markets. This accumulated knowledge bases helped these firms to identify opportunities to move up the value chain in terms of product complexities. In case of Ranbaxy the success of Cefaclor spurred them to invest in the Ciprofloxacin OD project. Cefaclor process development was the innovative outcome of research to manufacture the active pharmaceutical ingredient and this success spurred Ranbaxy's scientists to develop innovative product in formulation. This started Ranbaxy's ciprofloxacin once–a-day dosage technology development project and which proved to be company's first successful new drug delivery project. Ranbaxy's Vice President, corporate affairs suggests that.

"it's (reverse engineering) the foundation on which innovative R&D is built up. Without that, it was not possible to do that. If somebody to say that I would not look at all these capabilities but I would hire people and get going, it can happen for short run but it can not happen for long run".

This supports Pisano's (1994) view that process development is enabler to product innovation and can play a supportive role in product development.

The influence of accumulated knowledge and strong chemistry skill is reflected in the R&D strategies employed by all the sample firms in product R&D. All choose analogue research to venture into new drug discovery as this research strategy involves a strong chemistry base in terms of modifying the molecular structure to produce the drug with better efficacy or less side effects.

The next section analyses the mechanisms of knowledge acquisition used by firms to bridge the knowledge gap in innovative R&D research areas.

8.4.2 Acquisition of new competencies associated with innovative R&D

Knowledge acquisition is a learning related process by which knowledge is identified, accessed and obtained. The MNC pharmaceutical firms' transformed their internal R&D by hiring new personnel embodying the new technology to transform their technological identity as a response to biotechnological change. In post biotech era the 'star scientists' who combine genius and knowledge of emergent technologies became the gold deposits around which firms and their success was built (Zucker and Darby, 1996a).

The analysis of Indian pharmaceutical firms' approaches also show the important role of product R&D experienced scientists in acquiring innovative R&D capabilities. Along with that it also points out that that investment in internal R&D is played an important role in developing internal knowledge about innovative R&D in these firms. The innovative Indian pharmaceutical firms spent initial years in building infrastructure, putting together teams of scientists and developing organisational practises to manage innovative R&D.

8.4.2a Hired product R&D experienced as well as fresh scientists

Innovative Indian pharmaceutical firms started building innovative capabilities by hiring innovative R&D experienced scientists who have either worked overseas or in laboratories of multinational companies in India. According to NPIL's R&D president firms' first have get out of reverse engineering and start doing real research; hire the scientists who have the experience in product R&D areas. In India only a handful of scientists had experience in innovative R&D and these scientists became the 'guides' for the development of innovative R&D capabilities. Most of these scientists either had roots in Hoechst Research

Centre in India, as during its existence this centre was dedicated to new drug discovery and development or overseas working in MNC laboratories. These scientists formed the core teams in charge of designing and conducting of new drug discovery programmes. NPIL's R&D president explains role of senior scientists,

"you are there to pick the right people, those who know the business and then obviously they will drive something which is already exist in the company and they will bring something new which is required".

For the sample firms hiring these scientists played a key role in initiation of drug discovery research programme. These scientists had experience in drug discovery and they brought crucial tacit knowledge about drug discovery in the Indian firms. Due to their working experience in MNC R&D these scientists were well trained and had better exposure to new drug discovery technologies compare to existing scientific staff in Indian firms. Glenmark's strategic planning director suggests,

"they have got the exposure and the understanding about how the modern drug discovery works and that is very critical".

These scientists provided leadership to the discovery research teams and brought a coordinated approach in conducting a research programme. NPIL's strategic alliance director comments,

"there is lot more cross border transfer of ideas, huge number of Indian scientists abroad who are working in foreign pharmaceutical firms are coming back. At a cheaper cost they can recruit the groups around their idea and then make a much better innovation out of it. That's the first important trend, people coming back, ideas being done even in the US and groups being done here so lot more cross border things".

These core teams of scientists selected the research programmes and hired fresh scientists to create critical mass of drug discovery scientists. Research project teams for innovative R&D were built by focusing on fresh research talent rather than hiring those scientists experienced in reverse engineering. NPIL R&D president suggests,

"but generally you hire the new ones and you have the people who are abroad doing this sort of thing and pay them and get them, that way you are much better bet than trying somebody who has not done any innovative research for years and years in this area".

The innovative Indian pharmaceutical firms did not transfer the reverse engineering scientists into drug discovery research as reverse engineering activity is still going on in these firms.

The main constraint in innovative R&D for Indian firms was the lack of scientists with expertise in areas of medicinal chemistry and biology. Glenmark's strategic planning director suggests

"there are no people who have the expertise in biology. There are some people who have medicinal chemistry experience but very few people who have drug discovery biology experience".

To over-come this constraint these firms focused on hiring scientists from Indian as well as overseas universities and research institutes. Ranbaxy's former head of new drug discovery comments,

"at Ranbaxy I brought some people from US for molecular modelling, for microbiology, some for medicinal chemistry but that's the biggest challenge you have".

Firms' targeted returning post graduates and post doctorates from overseas universities. Currently around 20% of scientists working on innovative research projects have either trained at overseas universities, or have working experience abroad in MNC laboratories. DRL R&D president explains,

"Our target was returning post grads who have gone abroad to do either PhD or post docs, they were returning and were very good. Actually for 90% of workforce in the R&D, it was their first job, we were able to introduce scientific programme, induct people, mould them and could bring that culture into organisations. It is something nice to start with the clean slate rather than something that is there and erase it and then put it, it's a sort of double job."

Innovative Indian pharmaceutical firms like DRL used the relationship with academics in Indian universities to track fresh scientists for recruitment. DRF's former president explains,

"We rely heavily on university professors because most of their students are abroad. So we have enlisted support of the faculty here in various universities and from them found out what their students are, where they are and what they want to do and that allowed us to interact with those students overseas".

The number of scientists working in Indian firms has grown considerably in the last decade (table8.2). These firms are heavily recruiting the scientific staff to create a critical mass of innovative R&D experienced scientists and as a result the percentage of staff working in

innovative Indian pharmaceutical firms has consistently grown in last decade. For example, in case of DRL in just 1 year the percentage of people working in R&D has grown by 3%.

Table 8.2 Percentage of R&D staff to total staff (Source: Annual Reports, 2000-03)

Firms	Percentage of R&D staff / Total staff			
	2000	2001	2002	2003
Ranbaxy	8.85	9.02	11.11	13.52
DRL		9.09	12.39	
Wockhardt	9.57	11.11	12.47	13.66
NPIL	2.66	3.38	4.53	4.33
Lupin			5.45	6.11
Glenmark		5.55	6.00	10

8.4.2b Increased R&D investment

The most important feature of knowledge creation strategies is the level and direction of resources devoted to learning. The R&D departments provide a major source of learning in an activity which is central to firms continuing existence and prosperity. Dodgson, (1993) suggests the size and focus of R&D budgets are the primary factors encouraging and constraining learning.

Indian pharmaceutical firms began increasing their investment in R&D from 1995 but this only really gained momentum in 2000 (see Table 8.3). The focus of R&D investments in these firms has gradually shifted towards innovative process and product R&D. This has helped firms in creating the innovative R&D oriented knowledge base required for understanding the advances happening at the technological front. Cohen and Levinthal, (1990) points out that without investment in the creation of knowledge in particular areas, it is difficult for a firm to build capabilities required to acquire, absorb and apply external knowledge.

The sample firms set up the new R&D centres dedicated to innovative R&D equipped with state of the art instrumentation and at a different location with different practises than reverse engineering R&D. Glenmark's strategic planning director comments,

"those are separate people, it's a different thing altogether. They are set of completely different people that are operating it".

Table 8.3 R&D intensity of innovative Indian firms (source: Annual Reports, 2000-03)

Firms	No. of R&D labs	R&D intensity (R&D spend % of sales)			
		2000	2001	2002	2003
DRL	5	4.22	6.29	7.70	10
Ranbaxy	3	4.20	3.80	5.20	6.10
Wockhardt	2	7.20	6.20	6.20	7.90
NPIL	3	1.80	2.16	1.63	3.90
Lupin	1		2.41	2.30	3.09
Glenmark	2	1.45	3.50	4.41	6.52

Indian pharmaceutical firms did establish new disciplinary divisions and regulatory departments to support innovative R&D programmes. This was important as the ability of firms to make use of outside knowledge depends upon their installed knowledge base and the in-house scientific research creates the knowledge base which allows firms to take advantage of public sciences (Cohen and Levinthal, 1989; Gamberdella, 1992). Nicholl – Nixon (1993) shows that the establishment of internal R&D is an important pre requisite to the use of strategic alliances as a mean of acquiring external knowledge. Therefore internal investment in new disciplines allowed Indian firms to identify external sources of knowledge as well as nature of knowledge that should be accessed for acquisition.

Firms like DRL, Ranbaxy and Glenmark have also opened laboratories in US and Europe to make use of the knowledge spill-over and to attract research talent which was reluctant to shift to India.

Although over the years Indian pharmaceutical firms have steadily increased the R&D intensity, still it is much less compared to the R&D intensity of MNC pharmaceutical firms. In 2003 MNC pharmaceutical firms on an average invested 15.3 % of total sales in the R&D (PhRMA, 2004), while the average R&D intensity of the sample firms is 6.25%. The important factor determining R&D investments of Indian pharmaceutical firms is the cost of development of a drug in India could be a tenth of the international cost. DRF's former R&D president suggests,

"I think India has human resource cost advantage. By rough math 1/10th at MSc level, at PhD level it could be 1/5th and at upper level the difference could be 1/3rd".

However, according to a pharmaceutical consultant the innovative Indian pharmaceutical firms' actual R&D expenditure spent on innovative R&D has grown from 20% in 1995 to

40% in 2003. According to Forbes and Wield (2002) the focus of the R&D is far more critical to the success of industrial innovation than the level of R&D spending. The increasing level of scientific staff and R&D investments suggests that in Indian firms the focus of research is gradually shifting towards conducting innovative process and product R&D. DRF's former R&D president argues,

"I still maintain as a scientist and as a pharmaceutical research manager, in discovery area or phase, size or level of investments are not key factor of success. Success factors in innovative R&D are ideas and people with commitment, few people with commitment. So all this has been possible not because of the enormous deployment of the resources but it is just top level commitment, few dedicated scientists. They had urged to do something and demonstrate that we can also perform given the environment and that's what it is".

The analysis of firms suggests that these Indian firms built the core team of scientists to lead innovative R&D by hiring drug discovery experienced scientists and with the help of these scientists created the research teams by recruiting the fresh scientists from Indian as well as overseas universities and research institutes. The imitative as well as innovative process R&D has created a knowledge base with strong chemistry skills and this accumulated knowledge has built strong foundation for new drug discovery research in these firms.

The next section discusses the mechanism used by innovative Indian pharmaceutical firms to build culture of innovation in innovative R&D and to create an environment that supports the construction of common knowledge among the scientists.

8.4.3 Assimilation of new knowledge

The assimilation of knowledge involves the creation of an environment which facilitates processes of sharing experiences as without a shared language and a shared understanding, it is difficult to create uniform purpose, construct cohesive meaning, and learn in ways which support innovation across the organisation. The support offered by the organisation in terms of instrumentation, existing knowledge base and linkages creates conditions conducive for innovative research (Dodgson, 1991). Organisational environment, structure and practises can be designed by building supportive arrangements in order to attract personnel capable of creative and innovative ideas and research. Organisational routines are one way in which knowledge generated by individuals becomes assimilated or embedded in organisations (Nelson and Winter, 1982).

8.4.3a Culture of innovation

In terms of building a creative R&D environment NPIL's R&D presidents lists the important supportive arrangements,

"infrastructure has to be proper, instrumentation proper, growth possibilities should be there. So in case of scientist better ways of publication, possibilities of going to different conferences; all those things have to be there. The literature facilities, library facilities should be up to the mark".

For Indian firms attracting and retaining good research talent wasn't very easy and firms had to convince these scientists of their commitment by investing in the infrastructure required for innovative R&D. According to Wockhard's head of pharmacology,

"scientists who have worked overseas for 15 -20 years do come here but are not able to work here. Their expectations are very high about infrastructure and about capital equipment that they want".

Therefore the innovative Indian pharmaceutical firms' initial effort focused on creating ideal infrastructure required for innovative R&D and these firms covered the infrastructure limitations with various incentives. NPIL's strategic alliance director comments,

"we have to have this innovative thinking and in the past it's been very much I decide and you do. Now you have to say no you think and let's think together so more team based approach, innovative approach".

These companies are building culture of innovation by encouraging the creativity, providing freedom to work and absorbing the mistakes. According to Wockhardt's head of anti-infective research,

"company overcame the infrastructural limitations by creating platforms and opportunities for its scientists to learn; learn through failures, learn through success. allow them to fail so they can succeed later on, and absorb their failures sportingly".

In product patent era firms have realised innovation is key and therefore they are giving scientists freedom to experiment, make mistakes and learn from the mistakes. The freedom to work is provided in terms of opportunities to design research projects. Former R&D president of Ranbaxy explained,

"lot of time they come up with new ideas, this and that, we gave them opportunities to express what they want; you can try to see if that works. When new person comes, you must try new things and see what his abilities are. If you don't allow new people to work new ideas, then that is not the right thing".

The top level commitment played a crucial part in firms efforts to build innovative R&D environment and is reflected by consistent increase of investments in the innovative R&D. Firms which are run by leaders who are scientists have been able to balance this 'return on R&D investment' paradox well. DRF's R&D president comments,

"Scientists require good support from the management and that's what is important. Fortunately we have a leader who is a technocrat and then he is not a typical business man. That makes the big difference because he understands if somebody says chemistry is not working; he understands that, because he is himself a scientist".

8.4.3b Encouraging scientists to upgrade knowledge in areas of drug discovery

Indian pharmaceutical firms are now providing extensive training support to enhance scientists' research skills and scientific knowledge bases. In the case of fresh scientists firms give initial training for a period of six months. In some cases these scientists were rotated from lab to lab to evaluate their aptitude and skills. Then scientists were given independent task to perform by designing a research programme and giving them the opportunity to work on it. They were encouraged to read lot of patents and study structure-activity relationships. The focus is on how the patent holders started, what they did and where did they end up and after that scientists are encouraged to design their own molecules. This way of patent analysis provides a scientist an understanding of the intricacies involved in innovative drug discovery.

Table 8.4 Innovative Firms and affiliated university (Source: Annual reports, 2000-03)

No.	Firm	Affiliated university
1	Ranbaxy Laboartories ltd	Delhi University
2	Dr. Reddy's laboratories ltd	BITS, Pilani
3	Wockhardt	University of Mumbai
4	Nicholas Piramal (I) pvt ltd	University of Mumbai
5	Lupin Laboratories ltd	University of Pune
6	Glenmark pharmaceutical ltd	University of Mumbai

These Indian firms are also helping scientists to pursue their academic ambitions while working in organisations. The research centres in all these firms have been recognised by reputed Indian universities as authorised PhD centres and therefore post graduate scientists can commence their doctoral degree while working in these firms (Table 8.4). Due to these affiliations the researchers working in these firms get an opportunity to use university facilities such as library and laboratories. This has allowed scientists to pursue their

academic interests and helped firms' efforts in upgrading researching skills of its R&D staff.

Innovative Indian pharmaceutical firms are sending their scientists in India as well as overseas to different workshops, seminars and research institutes to undertake training in new scientific tools. NPIL's head of regulatory department comments,

"whenever there are some seminars outside we try to send our people, so we encourage our people to go to seminar outside because we are not so highly trained ourselves that we can train other people".

8.4.3c Changed R&D project management structure

Innovative Indian pharmaceutical firms have changed R&D project management structures to maintain a seamless flow of information inside the R&D department. DRF's former R&D president focuses on change in practise and comments,

"In the past results of the test used to be with head of department, he was sharing only whenever it was necessary. But now it is not like that. Chemist synthesises a compound, submits for screening and results will be shared among scientists. That activity stimulates a researcher so this type of seamless interaction and fluid flow of information helps in innovative R&D".

These firms started using a 'matrix' style of project management for organising and conducting new drug discovery research projects. For each therapeutic area project, there is project manager, project leader and team members comprises of both chemist and biologist. The project managers are responsible for project budget, planning and control, establishing objectives and ensuring they were met. These project managers are also in charge of coordinating resources drawn from various scientific departments. The matrix project management system has helped firms to create informal mechanisms of interaction; a platform for knowledge sharing by providing an opportunity for chemist and biologist to interact on a day to day basis. This has enabled firms to maintain high standards of work practise and uniform scientific development of the group through better communication among the scientists working on different projects.

Firms have created various forums to increase the interactions among members of different specialised groups. DRF's R&D president focuses on this aspect as most crucial for success in new drug discovery,

"we made it such a way that both chemistry and biology become seamless departments and the interactions are very informal; as informal as meeting people on the corridors of the labs', finding out what is going on or telling people what exactly they should be

looking into. These were a few fundamental things responsible and were really motivating factors, in addition to senior people like us; we are all telling them what they should doing. I would say that was one of the successful approaches".

Firms like DRL and Ranbaxy have licensed their molecules to MNC pharmaceutical firms for further development. These licensing collaborations have led lots of interactions at the scientists level between both firms and that has helped the Indian firms in imbibing some of skills in drug discovery management. DRF's former R&D president suggests,

"Scientists are interacting with their counterparts in these companies. We visit their sites, we have joint project meetings and all this information is shared. All this is very rich experience and we are happy about it. Today we are better project managers than in the past. We have formal mechanisms and processes for everything."

This analysis suggests that organisational practises like freedom to work, knowledge development opportunities along with matrix management structures have played an important role in creating cultures of innovation. These practises are shaping the development of organisational knowledge in innovative R&D by facilitating the relations and interactions among different parts of the organisation.

The next section focuses on the mechanisms of knowledge transfer used to create knowledge flows to access and acquire knowledge situated outside the boundaries of the organisation.

8.4.4 Mechanisms of knowledge transfer

A firm nurtures and creates knowledge through certain activities and these activities basically involve sharing of the knowledge within the organisation and the transfer of knowledge across organisational boundaries. Knowledge transfer here refers to transfer of useful know-how and information across and within the firm boundaries (Appleyard's, 1996). Henderson and Cockburn (1994) point out that externally focused integration: ability of firm to access knowledge from outside boundaries of organisation plays an important role in problem solving activities. In order to remain competitive in the biotechnology era, incumbent pharmaceutical firms have extensively used external relationships as a vehicle for adjusting their internal technological capabilities (Gamberdella, 1995; Nicholls- Nixon, 1993; Zucker and Darby, 1997). These changes led to transformation of new drug discovery and development in large pharmaceutical firms from a totally in-house activity to a networked collaborative activity. Therefore in recent years, a dense network of collaborative relationships among different types of firms and

other research institutions has emerged as a major feature of the transformation of large pharmaceutical firms' technological capabilities as a response to biotechnological change.

Similarly the analysis of Indian firms shows the emergence of the network model of collaborative R&D as an important mechanism of acquiring externally developed knowledge to augment internal capabilities.

8.4.4a Collaborative R&D

In the case of innovative Indian pharmaceutical firms networking has emerged as one of the key mechanisms for accessing and acquiring outside knowledge. These firms didn't have the skills, infrastructure or resources in-house to carry out certain functions and activities in innovative product R&D. Thus they collaborated and interacted with the Indian as well as overseas research institutes, universities to get their work done. DRF's R&D president explains the rationale behind the networking,

"drug discovery is very complicated and you may not have everything in house, we can't and we don't have everything in house so you have to. It's a sort of collaborative approach, a collaborative process. We have to really shake hands with the people who have got knowledge in this area, bring them as partner or bring them as a contract research for you, pay finite amount of money required for it and learn in the process".

This networking approach has changed the nature of the R&D in these firms, from an insular in-house R&D to a collaborative R&D model. Indian firms are building research networks by involving themselves in lot of joint projects with Indian as well as overseas research institutes, and research companies. Most of the innovative Indian pharmaceutical firms have set up special departments of strategic alliances and licensing to scout opportunities for collaboration. The members of these departments move around in different parts of world to find out what is happening and to initiate relationships in the specific areas of interest.

Successful knowledge transfer requires careful management of communication between involved entities as transfer of knowledge necessarily requires learning because technologies are based on tacit knowledge and their underlying principles are not always well understood (Bell and Pavitt, 1993). During such collaborations innovative Indian pharmaceutical firms give their scientists an opportunity to learn in areas of innovative R&D by sending them to work in collaborators' R&D department. DRF's former president elaborates on the approach,

"We were actually designing project with Havard Medical School. We are trying to organise collaboration with one of the faculty member in Harvard Medical School. He did not have the manpower and he could have hired manpower fresh only for this project but as project is exploratory he did not know how long it will go. So he said why you don't depute your own scientist and we are prepare to pay. We are happy whether something comes out of the collaborations or not, at least our scientist will get exposure. We are very progressive thinking along this line".

In areas of the clinical development of new chemical entities innovative Indian pharmaceutical firms are contracting out the development work to clinical research organisation. Wockhardt's head of pharmacology suggests,

"Only thing is three of crucial studies we need to contract out because those facilities are not here in India. People are not trained and it's cheaper to get those studies done from CROs than setting up in-house, that's another thing. We contracted out few studies and we did cost analysis and we found that if I get myself trained or anyone colleagues trained and then set up essay here, that is going to be more expensive".

8.4.4b Publication and patenting policies

Firms are changing their approach towards publication and now view it as an important tool to create an environment for creative research. NPIL's R&D president suggests,

"Publication is incentives there is no doubt about it. Somebody who is genuine scientist he would like to see he has a patent, he would like to see his publication. Ninety percent scientists, who are good and craved for discovery and if they have came in this business then that's exactly that they are looking for".

In innovative firms scientists' presentation and participation in conferences is strongly encouraged and looked as an important part of growth in scientist's research skills and the firms R&D knowledge flows. DRF's former R&D president:

"Publication is certainly an incentive to the scientist, there is no doubt about that and we also need to showcase our science, it stimulates scientists to think. If our people have gone and made presentations in a conference, then it's a validation of our science, showcasing of our science and also learning from others, all this adds to scientist stature as well company's reputation. "

The innovative Indian firms used publication and attendance in conferences as one of the way to create flows of knowledge between its scientists and scientific community outside the boundaries of the company. Glenmark's VP of chemical research explains,

"we go to different conferences; all are encouraged to attend major conferences in drug discovery to keep up to date and upgrade our knowledge. Attending the conferences is important as many things can be learned by reading publications. In our case we have to learn number of things and attending different conferences will also help in increasing the understanding".

However, all the respondents shared the viewpoint that patenting is the priority for all firms and a lack of trust is still preventing full-fledged publication from firms.

Increasing R&D commitment of the sample firms is matched by increasing intent in filing patents. DRF's former R&D president comments,

"Right from the beginning, we have tuned the mindset IP driven. Whatever they do, they should see whether it is worth patenting. Therefore people who are doing research work always look at whether there is novelty in what they are doing. The fact that they have recognised that there is novelty in what they are going to do and if they do it then they establish this novelty, that itself is a driving force for them".

The earlier analysis of knowledge transfer mechanisms suggests that the collaboration with research institutes and universities formed an important constituent in innovative Indian pharmaceutical firms' efforts to develop innovative capabilities.

The next section looks at mechanism employed by innovative Indian pharmaceutical firms to create cross disciplinary understanding among the scientists working on drug discovery research projects.

8.4.5 Integration of different knowledge bases

The product innovation management literature shows that the integration of different specialised knowledge bases and coordination of learning are crucial processes in building knowledge creation capabilities for innovation. The investment in organisational level integrative management practices facilitate interactions and creates knowledge among individuals situated in different parts of system independently (Un and Cuervo- Cazurra, 2004). Henderson (1994) suggests that in pharmaceutical R&D, the ability of the firm to integrate flexibly across disciplinary and therapeutic class boundaries within organisation is very important in success of drug discovery research.

Innovative Indian pharmaceutical firms strengthen the internal integration of knowledge by putting cross disciplinary teams in charge of the projects. Firms also used mechanisms like frequent formal and informal team meetings and reviews to create 'common knowledge' among various members of the team.

8.4.5a Cross disciplinary project teams

Indian pharmaceutical firms realised that it was not enough to just hire the scientists or build new R&D centres, the difficult part was to increase the cross disciplinary understanding of the scientists. NPIL's strategic alliance director comments,

"we are structuring our places of work to build more team spirit, to build more knowledge bases, to build more mobility. You should able to do cross disciplinary work much more because as I think new drugs are not going to be 'silos', they all are going to be cross disciplinary. So you might have pharmacologist, molecular biologist chemist, toxicologist, all different fields working for one drug".

In an innovative product R&D project the screening of molecules generates crucial information about the molecule in terms of structure-activity relationship. All the inputs of biological tests or results of screening have to be communicated to the medicinal chemist or chemistry team in a manner which is meaningful to the chemist. This information needs to be communicated on a continuous basis to minimise the development time and cost. Firms are using mechanisms like frequent meetings among project team members for increasing the interactions and communications between different specialised knowledge groups. The sample firms have set up cross-disciplinary teams of scientists from different disciplines like biology, pharmacology, medicinal chemistry, regulatory affairs for each therapeutic research area. This cross disciplinary team approach is also helping firms to achieve integration of different knowledge bases. According to NPIL's R&D president,

"scientists have to share the knowledge, it's not so as box that somebody can't talk to any other person. If there is particular problem, people would like to discuss among themselves. In our case we have discussions, we sit together and discuss. There are some mechanisms, as I said monthly meetings, weekly meetings; there are lots of things like that".

The aim of firms is to create a common knowledge base among the scientists working on project and achieve same level of understanding. In some firms such as NPIL, the internal formal meetings are held regularly weekly or fortnightly basis while informal meetings are held as and when need basis.

8.4.5b Review of research and Scientific Advisory Boards (SAB)

Periodic reviews of projects, departments and other relevant organisational sub units, plays an important role in managing knowledge flows across different parts of the R&D. An important aspect of review learning is learning from mistakes and failures (Dodgson, 1991). Coombs and Hull, (1998) point out that review procedure generates documents and shared knowledge which play an important role in contextualising knowledge and creating

shared categories for identifying ' that which is important'. The review mechanisms also play a role in locating skills and capabilities gaps in the R&D function and assist strategic decision making by highlighting the deficiencies in search, assimilation and communication process.

Indian pharmaceutical firms have put emphasis on review of research and institutionalised the process by creating the various forums. NPIL R&D president:

"we have culmination here, also the majority of the people have that. One is internal, internal reviewing is almost on weekly basis and monthly basis. Written down presentations and sometimes the external expert group is made. A sort of peer review to find out what's being done, have we done the right thing to check the milestone, if there is failure what is reason behind failure".

These review meetings are held quite often and in these meetings each scientist presents research work, which is critiqued, peer reviewed and further action plans are formulated. Firms are also used these internal review meetings for increasing the cross disciplinary understanding of scientists, as DRF former president indicates,

"when chemistry is being discussed, biologists will be present, when biology is discussed, chemists would be present and so a chemist will learn some biology, at least will appreciate what there difficulties are and vice versa".

Firms have also set up scientific advisory boards (SAB) with well known scientists from overseas as well as Indian academia and industry. SAB meet on every quarter or half yearly to review and provide advice on the research projects. This forum gives an opportunity to scientists from these firms to have closer interactions with experts. DRF's former R&D president:

"These scientists have diverse experience and rich knowledge backgrounds and they can critique. After the review meetings some of the members stay for 2-3 days to have closer interactions or discussions and all of which generates valuable feedback and build the confidence of researchers".

8.4.6 Summary

To sum up the analysis of the sample firms' learning processes suggests that the knowledge bases accumulated in reverse engineering R&D have built strong foundation for new drug discovery research in these firms. These firms acquired the knowledge in innovative R&D by hiring drug discovery experienced scientists and by creating a critical mass of innovative R&D scientists by recruiting the fresh scientists from Indian as well as

overseas universities and research institutes. Firms have also collaborated with research institutes and universities to access the knowledge situated outside boundaries of firms and created cultures of innovation by providing freedom to work and promoted cross fertilisation of ideas by encouraging scientists to attend and publish their work in the conferences.

The next section looks at the differences in approaches in knowledge processes in each firm and analyses the impact of those differences on the development of capability in innovative R&D.

8.5 Inter firm differences in knowledge processes

Technological learning is a process that permits a firm to accumulate technological capability over time. A diverse set of learning processes are necessary to build and accumulate knowledge or capabilities required to generate and manage improvements in processes and products. Therefore inter firm differences in operational performances are interpreted as an implication of different paths used for accumulation of technological capabilities (Dosi, 1988).

The analysis of innovative Indian pharmaceutical firms' learning processes showed the use various learning processes by firms to develop the capabilities in innovative R&D. In case of Indian firms, the different level of capabilities in product and process R&D suggests differences in organisational learning process. Therefore this section analyses the differences in learning processes employed to develop capabilities in innovative product R&D. The differences in firms' learning processes were analysed by comparing each firm on the basis of presence or absence different learning process and manner in which firm has organised and implemented particular learning process. It also discusses implication of differences in technology capability accumulation paths for innovative R&D capability development.

8.5.1 Firm level differences in mechanisms of knowledge acquisition

The innovative Indian pharmaceutical firms employed mechanisms or processes like learning by hiring scientists, increasing R&D investment and setting up new discovery R&D to acquire knowledge in innovative R&D; however an analysis of these mechanisms reveals the differences in terms of implementation and nature of knowledge access for acquisition.

In learning by hiring scientists, Ranabxy put more emphasis on hiring senior scientists working overseas in MNC labs than fresh post graduates. Ranbaxy's former R&D president comments,

"we have lot more qualified people, I wanted highly qualified people. Industrial research has base in fundamental research; there is no industrial research without fundamental research. So if that is case then people who have some fundamental knowledge it pays in the understanding".

Other firm like DRL built a critical mass of scientists by hiring returning post docs and doctorates. DRL's innovative R&D effort was led by India based scientists who had worked in innovative research areas in MNC R&D and these scientists built the sub teams. In case of DRL for 90% of scientists working in innovative R&D it was their first job in the industry. Lupin hired the scientists working in other innovative Indian firms like Ranbaxy who had the experience of innovative R&D while Wockhardt recruited scientists working in Indian academia and research institutes. NPIL started its innovative R&D research by acquiring the R&D facilities of Hoechst research centre in India. Hoechst research centre started operations in 1978 and throughout the period of existence this centre was involved with drug discovery research. Table 8.5 gives a graphic representation of the data.

Table 8.5 Inter firm differences in knowledge acquisition processes and mechanisms

No.	Knowledge acquisition processes and mechanisms	RAN	DRL	WOC	NPIL	LUP	GLE
1	**Hiring senior Indian scientists from MNC R&D overseas**	Present	Weak	**Absent**	Present	**Absent**	**Absent**
2	**Hiring fresh Indian post graduates, doctorates and post doctorates from overseas universities**	**Absent**	Present	Present	Present	**Absent**	**Absent**
3	**Increasing investment in R&D**	Present	Present	Present	Present	Present	Present
4	**Setting up new disciplinary units and regulatory department**	Present	Present	Present	Present	Present	Present
5	**Setting up discovery labs abroad**	**Weak**	**Present**	**Absent**	**Absent**	**Absent**	**Weak**
6	**Acquisition of R&D labs in India or abroad**	**Absent**	**Absent**	**Absent**	**Present**	**Absent**	**Absent**

Differences have also emerged in case of R&D investments and establishing R&D set up overseas. It has emerged all the firms are gradually increasingly R&D investment; however the magnitude and focus of the investments are different in each firm. In 2003 DRL has

invested 10% of its turnover in R&D whereas NPIL investment was only 4% (see Table: 8.3)

In terms of research strategy in innovative R&D all firms except DRL are adopting the cautious approach of analogue research. However, DRL is using an aggressive approach focused on acquiring skills in scientifically challenging research strategy of using structure-based drug design mechanisms. This is reflected in DRL's establishment of a R&D subsidiary in US. DRL, Ranbaxy and Glenmark have opened laboratories in US and Europe. However the focus and activities carried out at Ranabxy's US R&D laboratory, Glenmark's R&D set up in Switzerland and Reddy US Therapeutics (DRL's US R&D subsidiary) differs quite markedly. Ranbaxy and Glenmark overseas R&D set up focuses on clinical research and regulatory filling while Reddy US Therapeutics is focused on developing capabilities in discovering the molecule by using rational drug design strategy.

8.5.2 Firm level differences in mechanisms of knowledge assimilation

The analysis of knowledge assimilation processes or mechanisms in innovative Indian pharmaceutical firms shows the differences in firms' approaches in creating an R&D environment that facilitates sharing of knowledge and encourages innovative thinking. All the firms have started new disciplinary and regulatory divisions to foster learning in new areas but firms differed in terms of the internal arrangements needed to support learning in innovative R&D. Table 8.6 summarises this inter firm differences in knowledge assimilation processes and mechanisms.

Table 8.6 Inter firm differences in knowledge assimilation processes and mechanisms

No.	Knowledge assimilation processes	RAN	DRL	WOC	NPIL	LUP	GLE
1	**Scholarships to upgrade scientist's skill level**	Present	Strongly present	Present	**Absent**	Strongly present	**absent**
2	**Training programmes**	Strongly present	Strongly present	**weak**	Present	**weak**	**weak**
3	**Scientific advisory boards**	Strongly Present	Strongly Present	**absent**	Present	**weak**	Present
4	**Encouragement for Publication**	absent	Present	absent	absent	absent	Absent
5	**Encouragement for Patenting**	Present	present	Present	Present	Present	Present

DRL and Ranbaxy have set up supportive arrangements like incentive mechanisms for scientists to upgrade knowledge, training programmes and scientific advisory boards. In case of scientific advisory boards firm like Wockhardt have not formalised the relationships with experts by setting up scientific advisory board and instead are informally engaging with these experts on 'as and when needed' basis. NPIL's R&D president comments,

"scientists on the panel are very important people; some companies have put the people so it's not that you can't have it but can you afford to do this. That can be the question to begin with, you may not need to do it because you can't afford to start with. It's good to have it but it's not so critical that you can't start if you don't have big people sitting on your board or on your advisory board".

All firms are putting strong emphasis on patenting any novel research work coming out of the R&D labs. However, the significant differences emerge in firms approaches towards publication strategies. DRL has put equal emphasis on publication and patenting activity, but other firms don't conform to this philosophy and differs in their perception regarding importance of publishing. Therefore except DRL other firms are reluctant to publish the research work in scientific journals or conferences. NPIL strategic alliance director argues,

"I would say no, this is one thing we will not do. Why because today patent is so tricky I don't want to publish, full stop. Because I wanted to protect secrecy for the company, this is not an academic institution, this is a company; it needs to protect all its secrets and intellectual property to best of its ability. So it will publish only that which it sees useful".

However, gradually all firms are encouraging their scientists to attend various scientific conferences for stronger interaction with scientific community. For example, in 2003 NPIL presented findings on novel ant-cancer compound at conference on molecular targets and cancer therapeutics in Boston, US. Similarly Glenmark presented GRC 3886 molecule at four conferences in 2004 (Annual Reports, 2003-04).

8.5.3 Firm level differences in mechanisms of knowledge transfer

Innovative Indian pharmaceutical firms networking and collaboration strategy showed differences in terms of its intensity, targeted nature of knowledge and sources of knowledge used for accessing new knowledge. These inter firm differences involved in mechanisms or processes involved in transfer of knowledge are summarised in table 8.7.

Table 8.7 Inter firm differences in processes and mechanisms involved in transfer of knowledge

No.	Knowledge transfer processes	RAN	DRL	WOC	NPIL	LUP	GLE
1.	**R&D collaboration with Indian research institutes, universities**	Present	Present	**Absent**	Present	Strongly Present	**Absent**
2.	**R&D collaboration with overseas research institutes and universities**	Present	**Strongly Present**	**Absent**	**Absent**	**Absent**	**Absent**
3.	**R&D collaboration with MNC**	**Strongly Present**	**Strongly Present**	**Absent**	**Absent**	**Absent**	**Absent**
4	**Cross boundary movement of scientist**	Present	**Strongly present**	**Absent**	Present	Present	**Absent**

Ranbaxy and DRL have established a strong collaborative relationships with Indian and more specifically overseas research institutes and universities. Other firms like Lupin and NPIL are involved in collaboration with Indian research institutes in various areas of innovative R&D. Some of the collaborations by NPIL and Lupin are also partly financed by Indian government under New Millennium Indian Technology and Leadership Initiative (NMILTI). However, Wockhardt has chosen not to collaborate with Indian research institutes as top R&D management in the firm have different opinions towards such collaborations. According to Wockhartd's anti-infective R&D head,

"I don't think there is great amount of networking with research institutions within country. The small amount we do is purely need based, I don't call it real networking. Many of the government or CSIR based laboratories have different approach to research programmes; they don't have a focused kind of thing which industrial R&D need. The issues of timelines, commitment, and deliverance are very complicated and have a potential to become bitter. Initially we were a part of one research programme but at some stage we have to leave that programme because we felt that it was waste of time. I mean our experience of networking with research institutes in India is not very good".

Ranbaxy and DRL are also collaborating with MNC pharmaceutical firms through licensing and research deals. In 2003 Ranbaxy entered into alliance with Glaxo Smithkline (GSK) to discover and develop novel therapies in its four focus therapeutic areas.

Ranbaxy's other important collaboration in drug discovery R&D is with Medicines for Malaria Venture (MMV) Geneva, for the development of anti-malarial drug. Under this collaboration Ranbaxy's team of scientist will work together with University of Nebraska Medical centre, Monash University and the Swiss Tropical Institute to identify the lead molecule. Also both DRL and Ranbaxy have out licensed molecules to MNC pharmaceutical firms and which gives their scientists an opportunity to interact with scientists from MNC pharmaceutical firms.

These differences in approaches towards collaboration indicate the difficulties for a firm to move from an internally focused orientation and create knowledge flows to access knowledge situated outside the boundaries of firm.

8.5.4 Integration of different knowledge bases

All innovative Indian pharmaceutical firms have set up forums to facilitate the cross disciplinary integration of knowledge. Firms have adopted matrix form of R&D structure and set up cross disciplinary project teams to organise and manage innovative R&D activities.

Table8.8 Inter firm differences in knowledge integration processes and mechanisms

No.	Knowledge integration processes	RAN	DRL	WOC	NPIL	LUP	GLE
1.	**Organisational structure for R&D**	Matrix	Matrix	Matrix	Matrix	Matrix	Matrix
2	**Cross disciplinary project teams**	Present	Present	Present	present	Present	present
3	**Frequent review meetings with team members**	Present	Present	Present	Present	Present	Present
4	**Review meetings with external overseas scientists as reviewers**	**Absent**	Present	**Absent**	Present	Present	Present

All firms have employed mechanisms like frequent project team meetings and review meetings to maintain seamless flow of information inside the R&D. The only differences emerged in terms of setting up formal processes of having overseas external scientists as reviewers (table 8.8). This mechanism of the research review is absent in Ranbaxy and Wockhardt. Ranbaxy has set up the scientific advisory board headed by reputed Indian

scientist from Indian research institute who is involved in its research programme from the beginning while Wockhardt has formed internal review team with chairman as its head and uses external consultant only when it is necessary.

8.5.5 Firms' innovative performance and implications of differences in knowledge processes

The analysis of different learning processes shows the some of the processes and mechanisms were present and worked continuously in all firms, however their functioning and implementation differed in each firm. The difference in firms' approaches in terms of implementation and functioning have affected firms' access to external knowledge, internal knowledge sharing processes and application of existing knowledge bases.

Table8.9 R&D performance of innovative Indian pharmaceutical firms (Source: Annual Report, 2003)

No.	Firms	Innovative R&D performance			
		DMF (Drug Master File)	ANDA (Abbreviated New Drug application)	NCE patents (New Chemical Entity patents)	New drug delivery systems patents
1	Ranbaxy	44	127	6	4
2	DRL	56	35	8	
3	Wockhardt	17	32	3	1
4	NPIL			1	
5	Lupin	12	5	3	1
6	Glenmark	4		4	

DRL and Ranbaxy clearly show better performance in terms of innovative R&D although these two firms also started investing in innovative R&D comparatively earlier than other Indian pharmaceutical firms (table 8.9). But comparative analysis between these two firms reflects clear difference in their approaches towards the development of innovative R&D capabilities. For instance, DRL has chosen an aggressive research strategy and focused on acquiring capabilities in rational drug design approach to discover new chemical entities. It also adopted a more academic model of pharmaceutical R&D by focusing on publications, collaboration with universities and strong emphasis on scientists' skill up-gradation. DRL internationalised its R&D by establishing its subsidiary in US to acquire capabilities in rational drug design research. Ranbaxy used a different approach to develop the capabilities in innovative R&D. It built strong complimentary assets in advanced markets

by internationalising manufacturing, sales and regulatory functions. Ranbaxy also adopted cautious strategy of analogue research for discovering new chemical entities and hired the senior Indian scientists based overseas working in MNC pharmaceutical R&D rather than fresh scientists to acquire capabilities in innovative R&D.

In follower firms like Wockhardt and NPIL innovative R&D effort began in mid 1990s while Lupin and Glenmark started investing in innovative R&D by late 1990s. Wockhardt started with biotechnology as main research area and building on that firm started developing capabilities in innovative R&D. Unlike other Indian pharmaceutical firms Wockhardt has focused only on one therapeutic area, anti-infective, as its innovative R&D focus and filled the capability gaps through contract research with overseas research companies compared to R&D collaboration with Indian research institutes and universities. Wockhradt created a core team of scientists by hiring scientists from Indian research institutes and academia. The other follower firm NPIL, the youngest firm compared to other innovative Indian pharmaceutical firms, has over the years grown on the basis of using acquisition as means for growth. It thus bought the Hoechst Research Centre to acquire capabilities in innovative R&D. Also, NPIL is not targeting the generics market in advanced countries and has instead chosen the strategy of partnering with MNC and generic pharmaceutical firms for contract manufacturing and custom synthesis.

A late starter like, Lupin hired senior scientists from other innovative Indian pharmaceutical firms like Ranbaxy and established strong relationships with Indian research institutes for collaborative R&D programmes. Lupin is actively promoting joint working and transfer of scientists in collaborating research institutes to train its scientific workforce in innovative R&D.

The other late starter, Glenmark is a small firm compared to other Indian pharmaceutical firms and its innovation R&D learning strategy reflects the limitation of size. Glenmark have small team of scientists working on new drug discovery research programmes which are directly supervised by firm's managing director.

The analysis of innovative Indian pharmaceutical approaches and performance shows the firm level differences involved in development of capabilities in innovative R&D. Each firm has adopted a strategy which differed from each other in terms of functioning and implementation of different learning processes. Firms need diverse set of learning mechanisms and reliance on a single mechanism is unlikely to yield any effective organisational learning (Figueiredo, 2002). The evidence suggests that functioning and implementation of diverse set of learning processes plays a crucial role in technology capability accumulation and a continuous effort should be made to improve the learning processes particularly their functioning and implementation. Therefore, firms needs a

consistent and continuous strategy to manage and organise the diverse set of learning processes implying learning at firm level is neither linear nor automatic process and requires a deliberate learning strategy.

8.6 Conclusion

This chapter analysed difficulties and mechanisms involved in movement of innovative Indian pharmaceutical firms from imitative R&D capability to innovative process and product R&D capability as a response to change in patent law. The analysis suggests that based on imitative process R&D, innovative Indian pharmaceutical firms built capabilities in innovative process R&D and simultaneously invested in development of innovative product R&D capabilities. This ambidextrous capability development (O'Reilly and Tushman, 2004) allowed Indian firms to exploit its process R&D capabilities, which these firms have accumulated in reverse engineering era and provided an opportunity to explore areas in innovative product R&D. The analysis also suggests that as firms move from imitative process R&D to innovative product R&D, they will have to jettison some capabilities which were useful in process R&D but can become rigidities in product R&D. Therefore in case of innovative Indian pharmaceutical firms unlearning of obsolete abilities has emerged as an important constituent in development of new capabilities in firms.

This chapter also analysed firm level learning processes involved in development of knowledge creation capability for innovation in firms under study. It focused on firm level learning processes involved in acquisition, assimilation, transfer and application of new knowledge. The evidence shows that innovative Indian pharmaceutical firms 'created a research tradition' by developing non-infringing and novel processes for drugs in imitative R&D and that led the foundation for the development of competencies required in innovative R&D. These firms consistently increased R&D investment and hired the new scientists embodying the innovative R&D knowledge to acquire the advance level capabilities in pharmaceutical R&D. These scientists carried the crucial tacit knowledge with them and played a significant role in changing the mindset of the organisation. These firms created an environment that facilitated the sharing of knowledge among its R&D scientists by setting up various supportive arrangements like matrix form of project management and cross disciplinary project teams. Some also collaborated with research institutes, universities to augment and leverage organisational capabilities in innovative R&D. The analysis of learning process further revealed that functioning and implementation of these learning processes differed in case of each firm, showing that

learning at firm level is neither automatic nor linear and requires a deliberate learning strategy.

Chapter 9

CONCLUSION, CONTRIBUTION AND IMPLICATIONS

In this final chapter the findings arising from specific research activities are discussed with regards to research questions raised at the beginning of the thesis. It presents principle findings of the research and discusses managerial, policy and theoretical implication of the research findings. The limitations of the research project are discussed with respect to possible future research that could be undertaken.

9.1 Introduction and Summary

The influence of TRIPS (Trade Related Intellectual Property Rights) as part of WTO (World Trade Organisation) agreement on industries from developing countries formed the genesis of the research. Now due to TRIPS agreement all the WTO member countries will move from no or partial patent protection to fully fledged patent protection. As a result all WTO member countries will have uniform strong patent law and restriction on use of reverse engineering as a legal mechanism of knowledge acquisition. This represents a radical break with the past in which developing countries typically had only weak levels of patent protection. In this context this research examined the influence of patent law on the strategic orientation and technological capability accumulation process in Indian pharmaceutical industry. It specifically focused on the learning processes involved in development of innovative R&D capabilities in the Indian pharmaceutical firms as a response to strengthening of patent law.

This research mainly concentrated on the pharmaceutical industry as the access to technology is relatively difficult in this sector. New product development in this area involves highly professionalized and specialised technological R&D activities. The learning process involved in development of pharmaceutical manufacturing and R&D capabilities is much more complex compare to other sectors. The large multinational firms that dominate this sector develop a significant proportion of knowledge and through patent effectively control the diffusion of knowledge. These firms conduct most of their activities at home or in other developed countries and prefer direct investment to licensing when producing abroad. Therefore most of the developing countries have built domestic pharmaceutical industries by adopting weak patent laws which allowed these countries to overcome the patent barriers in acquisition of patented knowledge. In a similar way to the Indian pharmaceutical industry, the pharmaceutical industries from these countries will be severely affected by the TRIPS agreement. Therefore this research on capability

development in the Indian pharmaceutical industry has important managerial and policy implications for firms and industries in other developing countries which are facing the TRIPS challenge.

The research presented in this thesis differed from previous studies of the patent system in developing countries. It employed a capabilities approach to the study of industry and firms responses to the strengthening of patent law. The Chapter 2 points out that the most of the literature on the patent system in developing countries has

a. focused on socio economic issues like pricing of the drugs and welfare cost (Lanjouw,1996;Watal, 2000; Scherer and Watal, 2001; Pangariya,1999:Nogues,1993)

b. investigated the link between strengthening of patent system and its effect on the technological development (Sequeria, 1998; Kumar,2003; DEste,2002) and

c. analysed the effects of strong patent system in output and trade performance of the industry (Weisburst and Scherer,1995; Felker et al., 1997).

This research focused on the impact of the strengthening of patent law on learning processes involved in technological capability development and analysed mechanisms used by firms to transform their capabilities.

Technological capability building is an issue that has been widely discussed in the last 20 years by different theoretical research traditions. Technological capability consists of stocks of resources needed to generate and manage technical change including skills, knowledge and experience and institutional structures and linkages (Bell and Pavitt, 1993). The research on developing countries mainly focused on the issue of long term process of technological capabilities accumulation in industries. To a larger extent, this literature discussed capability development in developing countries referring to importance and difficulties associated with various formal and non formal mechanisms of knowledge transfer. It pointed out that the firms in developing countries compete on the basis of production capabilities, largely acquired from elsewhere and reinforced by basic to intermediate technological capabilities related to a simple knowledge base.

However the increasing specialisation of knowledge is limiting the existing modes of formal and non formal technology transfer. The widening gap between kinds of knowledge and skill required to imitate or operate given technology and the kinds of knowledge required to create, generate or change technology has reduced the possibilities of acquiring the latter largely by experience in the former (Bell and Pavitt, 1993). In addition to that the fast pace of change in markets, technology and competition are making existing firm and industrial level capabilities redundant. Therefore in this new era the ability of a firm to create new knowledge for innovation has become strategically important capability. The area of rebuilding or reconfiguring of capabilities has been addressed by the strategic

management literature (SML), by focusing on innovative firms competing at technological frontiers in advanced countries. This research studied learning and capability building concerned with sustaining, deepening and renewing of the existing innovative capabilities by focusing on most innovative firms competing at the technological frontier in advanced countries. Therefore there is a flourishing literature available on the firm specific factors that affect the success and failure of innovation in advanced countries, but there is no literature of equivalent scope and depth for developing countries (Bell and Pavitt, 1995).

The main difference is in the object of analysis, the firm in a developing country and its external environment as opposed to a firm in the developed world and its environment. In the case of firms from developing countries economic, political and social complexities makes the transformation of capabilities a challenging and difficult process. The availability and access to technical knowledge for firms from developing countries is an important issue and so literature on the developing countries is mostly focused on the technical knowledge dimension of the building up of technological capabilities. However, Bell and Pavitt (1993) points out that the technical as well as organisational dimension of managing knowledge is crucial in building capabilities for innovation. The research on developing countries has to a larger extent focused on the accumulation of stocks of technological knowledge, and much less on the specialisation of knowledge bases and other firm level issues like coordination and integration of knowledge across organisational boundaries. Thus research focused on capability development in developing countries the organisational dimensions of managing technical knowledge needs more attention (Chapter 3).

Some of the researchers like Kim (1997a), Duténit (2000) and Figueirdo (2003) focused on the organisational and managerial issues involved in the development of innovative capabilities. These researchers mostly focus on firm level learning processes involved in establishing a base of technological knowledge that did not previously exist as opposed to the renewing accumulated knowledge base or using that knowledge base in a different way. The change generating capabilities have become increasingly more complex and specialised as they have differentiated from the capabilities required to use them (Bell and Pavitt, 1993).

This research mainly investigated these change generating capabilities by focusing on learning processes used by Indian pharmaceutical firms to transform existing capabilities and develop innovative R&D competencies as a response to strengthening of patent law. It also covered the technological capability accumulation process in the Indian pharmaceutical industry and the impact of strengthening of patent law. Thus this research contributes to this neglected area of research in the developing countries literature by

investigating the transformation of capabilities and development of new capabilities in firms from developing country.

It addressed two key questions through a case study of the Indian pharmaceutical industry and six innovative firms.

- **How are firms from a developing country building a strategic knowledge creation capability for innovation as a response to the forces of globalisation?**

Specific:

- **How are Indian pharmaceutical firms re-building capabilities for innovative R&D as a response to TRIPS agreement?**
- **How relevant is knowledge accumulated through imitation for firms in their efforts to create innovative novel products?**

The research took the firm as unit of analysis and the dynamic process of technological learning as its focus. This dynamic and complex process of technological learning was explored by developing a theoretical framework drawing on the strategic management literature and organisational theory literature focused on knowledge, learning and innovation. It explored the social processes or mechanisms used for knowledge acquisition, transfer, assimilation and application. It also explored the relevance of prior knowledge base in a new environment and processes involved in building it.

Thus this research shows the learning processes or activities involved in the development of a knowledge creation capability for innovation in firms from a developing country as a response to change in the external environment.

9.2 Limitations of the research

This research is limited by several factors. One set of limitations concern the validity of indicators such as number of patents, nature of patents, R&D expenditures and staff ratios. These kinds of problems are discussed in the research methodology chapter and care has been taken in interpreting trends from indicators. For example, no firm conclusions were drawn based solely on trends in indicators such as patents or R&D intensity.

This research explored capability development in firms from developing countries by focusing on 6 firms in 1 industry from developing countries at one point in time. The theoretical framework linking different learning processes guide the investigation in firm level learning processes involved in capability development. This framework covers learning processes involved in acquisition, assimilation, transfer and application of

knowledge. Therefore other areas which can play an influential role in capability development such as nature of firm at birth or role of top management remained outside the scope of this research.

This research focused on the capability aspect of new chemical entity research in the pharmaceutical industry. The pharmaceutical industry is known for keeping secrecy on NCE research and due to confidentiality reasons some firms denied access, while those granted access declined to share information. Managers from sample firms that did give interview were generally unwilling to provide data due to confidentially reasons. For example, firms declined data on composition of scientific staff and their distribution in research projects, which would have helped in analysing division of labour in R&D.

In regard to case studies the main limitations were the depth of analysis possible due to reliance on a few key individuals and the difficulties in accessing historical firm records. The selection of cases was restricted by time available and willingness of individuals from firms to participate.

The interview method of data collection had certain limitations. The individuals contacted for the interview were high ranking managers of the firm and therefore struggled to allocate more than one hour. This also affected the depth of information that could be obtained. Due to busy work schedule of these managers and distance problem between UK and India, the opportunities for repeat interviews were fairly limited, which affected the feedback on case studies.

In using interview data important care needs to be taken to understand and differentiate between managers' or firms' intent and perception of reality, as expressed by managers in interviews, from the 'reality' of what is happening in practise. The qualitative research methodology literature suggests triangulation of evidence by using multiple sources of data as a mechanism to overcome the problem of bias (Yin, 1994). In this research triangulation of the responses from case study was intended to come from comparison of interview responses, firm's annual reports, analyst presentations, other published matter on the firm and coverage in national and business press. During the case studies it became apparent that the lack of availability of publication and patenting data on Indian firms as well as lack of access to internal firm data hampered the triangulation, giving rise to the problem of bias.

However despite these limitations, the research represents a substantial advance in our knowledge and understanding about the learning process involved in the development of advanced level of capabilities in firms from developing countries. The rest of the chapter outlines the principle findings and their theoretical, managerial and policy implications. The discussion suggests that the transformation of capabilities in the Indian pharmaceutical

industry has important implications for firms in other developing countries in their response to strengthening of patent laws. But direct adoption of the Indian pharmaceutical industry's approaches to other developing countries may not be feasible as these countries differ a lot in economic characteristics such as institutions and factor markets.

9.3 Principle findings

The evidence showed that Indian pharmaceutical firms developed basic capabilities in pharmaceutical R&D cumulatively by adopting two forms of imitation; duplicative imitation followed by creative imitation. It also reveals that the strengthening of patent law accelerated the movement of Indian pharmaceutical firms towards development of innovative product R&D capabilities. It points out that the innovative Indian pharmaceutical firms developed innovative R&D capabilities by learning beyond their core areas; using prior knowledge base and employing mechanisms like collaborative R&D and hiring product R&D experienced scientists.

9.3.1 Firm level processes involved in development of knowledge capability for innovation

The main research question of the thesis concerned processes and activities involved in development knowledge creation capability for innovation in Indian pharmaceutical firms. The transition from basic capabilities to advanced innovative capabilities represents a movement from simple knowledge base to complex knowledge base. This research shows that development of new capabilities involved removal of capabilities which were redundant in new era, acquisition of new knowledge and combination of new knowledge with existing relevant capabilities.

The analysis revealed that in the case of Indian pharmaceutical firms the main rigidities that emerged are

a. imitative R&D organisational routines,

b. in-house nature of R&D and

c. organisational mindset shaped by short term vision of R&D investments and domestic market focused approach.

In the case of Indian pharmaceutical firms getting rid of 'rigidities' accumulated in the reverse engineering era formed the important part of learning innovative R&D capabilities. The Indian pharmaceutical firms used networked model of collaborative R&D and learning by hiring as main mechanisms of knowledge acquisition. These firms collaborated with MNC firms, research institutes and universities to augment and leverage organisational

capabilities in innovative R&D. They created linkages with Indian as well as overseas research institutes to fill the knowledge gaps and train its scientific workforce.

The Indian pharmaceutical firms consistently increased the R&D investment and hired the Indian scientists embodying the product R&D knowledge to acquire the capabilities in innovative R&D. These firms hired product R&D experienced Indian scientists working overseas in MNC pharmaceutical R&D firms or universities to acquire the know-how in innovative product R&D. These scientists carried the crucial tacit knowledge with them and enhanced the absorptive capacity of firms by helping them in identifying and acquiring appropriate technologies. They helped Indian pharmaceutical firms to access knowledge in areas of innovative pharmaceutical R&D through their linkages among other scientists working in this area and thus considerably reduced the time and cost of acquiring knowledge in innovative R&D. These returned brain played a significant role in changing the mindset of the organisation by adopting 'new ways of doing things' in R&D in Indian pharmaceutical firms. Therefore the Indian scientists working in advanced countries like US and UK have emerged as an important source of knowledge in areas of innovative R&D for Indian pharmaceutical firms.

The analysis points out that Indian pharmaceutical firms put extensive emphasis on creating an environment that facilitated assimilation of new knowledge among its scientific work force. These firms set up various supportive arrangements to encourage the sharing of knowledge among its R&D scientists. For example, the firms adopted a matrix form of project management, started sending scientists to attend the premier scientific conferences and institutionalised the process of reviewing research by establishing scientific advisory boards with internationally reputed scientists. These organisational mechanisms along with increasing R&D investment allowed Indian pharmaceutical firms to create the necessary infrastructure for innovative R&D and helped these firms to attract the top research talent.

The analysis of organisational mechanisms also showed the strong emphasis on integration of different knowledge bases in all Indian pharmaceutical firms. These firms adopted measures like cross disciplinary teams and frequent scheduled as well as ad hoc project meetings to achieve the integration of different knowledge bases.

This research reveals that the learning process adopted by Indian pharmaceutical firms shared similarities with the large multinational pharmaceutical firms' approaches to transform their technological identity as a response to molecular biology advances. Large pharmaceutical firms hired star scientists working in academia and adopted a network model of collaborative R&D to transform their technological identity and capabilities. This suggests that as far as intra firm learning is concerned, learning processes followed by technology frontier firms are also applicable to firms from developing countries. However

the nature of the institutional environment and socio economic factors differs a lot in developing countries compared to advanced countries. Therefore in developing countries firms have to modify learning strategies according to the external environment.

9.3.2 Inter firm differences

The analysis of Indian pharmaceutical firms revealed inter firm differences in functioning and implementation of learning processes, showing that learning at firm level is neither automatic nor linear and requires a deliberate learning strategy.

Inter firm comparative analysis shows the subtle differences in learning processes in each firm. For example in the case of hiring the product R&D scientists, the nature of scientists targeted for recruitment as well as sources used by firms for recruiting new scientists differed a lot. Similarly inter firm differences emerged in supportive learning mechanisms which influenced the creation of the environment that encourages interaction among distributed knowledge systems and facilitates the development of collective knowledge. The learning mechanisms like incentive policies, top management commitment and emphasis on collaboration and networking differed across the firms. The rate at which a firm moved in accumulating capabilities and the subsequent level of sophistication varied as does the potential sequencing of capability development among different functional areas. This suggests that the transformation from imitative R&D to innovative R&D is neither linear nor automatic and needs a deliberate learning strategy.

The differences in implementation and functioning of learning processes also suggest that firm engaged in different modes of learning in their response to external conditions and that emerged as one of reasons for inter-firm differences in firms' innovative R&D capabilities. This finding support the observation by Figueiredo (2003) that the way in which intra firm learning processes and mechanisms are managed over time plays a substantial part in influencing inter firm differences in terms of technological capability and, in turn, in competitive performance.

9.3.3 Technological capability accumulation process in Indian pharmaceutical industry and TRIPS

The Indian pharmaceutical industry's journey from being an import dependent industry to a developer of original pharmaceuticals has been a long and eventful one. This research presented a model of dynamic learning processes involved in technology capability development in the Indian pharmaceutical industry. It illustrates that the industry has built its technological capabilities by moving from basic to intermediate innovative

technological capabilities and finally, as a result of change in patent law, the industry is undergoing learning to develop capabilities in innovative R&D.

The technological capability accumulation process in the Indian pharmaceutical industry followed the trajectory of starting with duplicative imitation followed by creative imitation to rise up the value chain of pharmaceutical R&D. The weakening of patent laws in 1970 played a crucial role in shaping and building the Indian pharmaceutical industry. It reduced market entry barriers, legalised reverse engineering and created a competitive domestic market.

The evidence presented in this thesis strongly suggests that the weak patent system was the dominant influence on the development of basic and intermediate capabilities in the Indian pharmaceutical industry. It legalised reverse engineering, (an important non-market mediated mechanisms of knowledge acquisition) whilst allowing the Indian pharmaceutical industry to learn and improve its process R&D capabilities and expand production and marketing capacities.

The nature of the domestic market and industrial policies adopted by the Indian government also influenced the development of capabilities in the Indian pharmaceutical industry. The intensely competitive domestic market fuelled firm based learning and assimilation of basic capabilities bringing about industrial transformation and development. But the lack of value and protective nature of the market also prevented the development of innovative capabilities.

This research shows that the strengthening of patent law had a positive impact on large Indian pharmaceutical firms and catalysed their movement from imitators to innovators. It was emphasised in chapter 6 that the strengthening of patent law changed strategic orientation of the Indian pharmaceutical industry and forced firms to pursue alternative innovative technological trajectories. The Indian pharmaceutical firms responded to the strengthening of patent laws by adopting an ambidextrous technology capability development path in the form of innovative process and product R&D. The Indian firms improved on the basic capabilities incrementally by competing in advanced countries' generics market and supplying drugs to MNC. In parallel, these firms developed capabilities in innovative product R&D.

The generics product R&D created economic resources for Indian firms to fund the investment in exploration of radical capabilities. It allowed these firms to exploit their process R&D capabilities and explore areas in innovative product R&D. This exploitive use of process R&D helped Indian firms to develop the complimentary capabilities required to compete in product markets and reduced the Indian firms' dislocation from international sources of pharmaceutical innovation, technology and research.

The imitative R&D in these firms created important essential basic capabilities and that acted as a base for innovative R&D. The basic and intermediate innovative capabilities learnt as a result of imitative learning certainly gave these firms a solid base for the development of competence in advanced innovative R&D.

To summarise the principle findings of this thesis are:

A. **Imitation played a key role in development of basic and intermediate capabilities in Indian pharmaceutical industry.**
B. **TRIPS acted as a catalyst and accelerated movement of Indian firms towards innovative R&D.**
C. **The unlearning of rigidities of reverse engineering era like imitative R&D mindset, emerged as key aspect of learning.**
D. **Indian firms used mechanisms like collaborative R&D and hiring the scientists experienced in product R&D to acquire knowledge in innovative product R&D.**
E. **The Indian firms built creative R&D environment by adopting mechanisms of managing knowledge which facilitated and fostered sharing of knowledge among scientists.**
F. **The inter firm differences in learning processes and its impact on capability development shows that at firm level learning is neither automatic nor linear and requires deliberate learning strategy.**

9.4 Implications of the thesis and future research

This section discusses theoretical, managerial and policy level implications of the research findings. This thesis has drawn on an empirical analysis of the Indian pharmaceutical industry to investigate the process of innovative capability development in firms from developing countries. It focused on the upstream segment of the drug innovation cycle, specifically the discovery aspect of pharmaceutical R&D.

The application of results from this research in other developing countries can pose problems due to subtle differences between developing countries' economies and institutions. Broadly all the developing countries share some of the features in terms of economic parameters but importantly there are some subtle differences which make each country unique. Indian pharmaceutical industry ranks as one of the most advanced science based industries among developing countries in terms of sophistication and capabilities. Some of the factors that helped this industry include availability of trained English speaking manpower, institutions, and knowledge seeking culture. The influence of these factors puts limitation on the extent to which findings of the research can be applicable to

other developing countries. Therefore while drawing implications for other developing countries, it is important to remember that each country starts from its own unique set of advantages and disadvantages. There can not be direct transfer of the Indian pharmaceutical industry's growth model to other countries. However the insights identified in this research do present important general considerations.

9.4.1 Theoretical framework for analysing capability development in firms from developing countries

The theoretical framework presented in this thesis for exploring the development of innovative R&D competencies in firms from developing countries provides a novel way of analysing the complex set of internal organisational factors involved in capability development. It integrates both the competence based view of knowledge and organisational behaviour view of knowledge by focusing on socially embedded qualities of organisational knowledge as a crucial part of the capability development process.

This theoretical framework shares similarity with the analytical framework developed by Kim (1999) in terms of theoretical foundation. Kim (1997a, 1999) proposed an analytical framework based on absorptive capacity concept to explore capability development in South Korean firms. Similar to that the theoretical framework developed in this research is based on absorptive capacity concept; the ability of firm to evaluate, assimilate and apply outside knowledge (Cohen and Levinthal, 1990). However this framework differs with Kim's (1997a) analytical framework in terms of its treatment of capability development. This research views development of innovative R&D capabilities as a complex interactive process built on the situated actions of organisational members as they engage in the world. The theoretical framework focuses on the activities and processes that play a fundamental role in driving and shaping organisational knowledge by facilitating the relations and interactions among different parts of the organisation. The absorptive capacity is viewed as a function of two separate but interrelated dimensions:

a. the firm's ability to acquire the knowledge relevant to the new technological paradigm and

b. firm's ability to integrate external knowledge into existing capabilities.

The absorption of knowledge depends on the accumulated knowledge base and mechanisms of knowledge transfer (Cohen and Levinthal, 1990). Based on these concepts, the capability development in the theoretical framework is divided into a series of sub-processes (prior knowledge base and knowledge transfer, acquisition, assimilation, integration) and analyses the Indian pharmaceutical firms by focusing on the activities or mechanisms involved in these sub processes.

The theoretical framework and subsequent research activities have uncovered the nature of the firm level learning processes and provided insight into how they affect an organisation's ability to capture, assimilate and apply knowledge to commercial ends. This framework helps firms and researchers to identify and analyse activities that may influence the technological capability development process. Although the theoretical framework has its limitations in the fact that, whilst it expresses the nature of the internal organisational processes, and identifies number of key areas that constitute such processes, it does not itself operationalise these processes. It shows the mechanisms adopted by the innovative Indian pharmaceutical firms for creating contexts to facilitate the technological learning and capability development in innovative R&D. To this extent the framework developed in this research functions as a tool or vantage point from which to explore the issues involved. The theoretical framework itself is not operational as it does not lend itself to any form of prescription.

9.4.2 Learning processes

The accumulation of technological knowledge is complex and often a costly process of technological and organisational learning. Bell et al., (1984b) point out that absence of sustained efforts to acquire and use the capabilities necessary for continuous technological change often results in failure of learning processes in firms from developing countries.

It is sometimes suggested that firms in developing countries have accumulated technological capabilities in particular sequences, moving through definable stages (Dhalman, et al., 1987). The learning hierarchy model suggests that NIC progresses from learning to produce, learning to produce efficiently, learning to improve production, learning to improve products and finally culminates in learning to develop new products. It has even been suggested that these sequences and stages can provide guidelines for both firm level strategies and government policies.

In a very general sense, such sequences do reflect realities. For example firms in different industries seeking to improve their technologies generally have to build on what already exists. Beyond such guidelines however rigid ideas about sequences and stages may be misleading, especially at the firm level. This research shows that the learning processes which underlie accumulation and development of knowledge require technical as well as organisational knowledge management capabilities. The important aspect of this learning involves unlearning the competencies which might have been useful in an earlier era but not relevant in new environments. The doing aspect (the link to production experience) remains necessary but not sufficient to development of innovative capabilities. Thus this research points out that the move from basic to intermediate and to advance level

capabilities is neither linear nor automatic. It requires a deliberate effort from firms to invest in different mechanisms of learning. This finding supports observations made by researchers like Bell and Pavitt (1995), Forbes and Wield (2002) that technological learning is neither automatic nor linear and depends upon the decisions firms make.

The variability of the technological accumulation patterns suggest that the need for care and clarity in choosing specific strategies for accumulating technologies at firm level. Knowledge acquisition through practice often happens in social contexts (Lave and Wenger, 1991). Much of the knowledge generated through R&D activity is of a tacit nature and located in the specific context in which it was developed (Nelson and Winter, 1982). Chataway et al., (2003) suggest that the challenge faced by social knowledge is that it may not be acknowledged by management. Bell and Pavitt (1995) pointed out that there are few guidelines for firms to follow in designing strategies to move from the basic level to the advanced level of capabilities.

In this regard the findings of this research provide insights for R&D managers in terms of activities involved in creating an environment that facilitate the development of a knowledge creation capability for innovation. This research emphasises the importance of these organisational mechanisms in innovative new product development and points out various organisational mechanisms like cross disciplinary teams and frequent project meetings involved in integration of various knowledge bases. It shows the distinct role of knowledge management strategies in shaping the learning environment that facilitated transformations of technological capabilities in Indian pharmaceutical firms. To a larger extent knowledge creation depends on absorptive capacities but as the Indian pharmaceutical industry's example shows some things like firm based strategies, policy measures, mechanisms of knowledge management and their networks make the difference. The Indian pharmaceutical firms' development of innovative R&D capability suggests that the firms and networks can become more adept at creating learning environments which enhance sense making and sourcing capacities.

The importance of these internal activities in the capability development process raises an important implication for firms in Indian industries as well as other developing countries. The limited resources typical in many firms in developing countries hinders their ability to provide necessary environments in terms of recruitment of talented personnel, extensive knowledge sources, training and organisational mechanisms to facilitate capability development. Hence in the future, emphasis of the technology policy should be on providing mechanisms that will help firms increase their awareness and access to external knowledge. Technology policy should assist firms in creating linkages between their

internal capabilities and external knowledge and help in assimilating these associations into business opportunities.

The research on developing countries suggests that technology development patterns vary within developing countries. Technology capability developments in East Asian countries share similarities with each other in terms of state intervention in some industries designed to protect and accelerate achievement of international competitiveness through attainment of the requisite technological capabilities. In this context comparative studies between these industrialising countries and newly emerging countries like India and China would be useful in building more comprehensive models technological development and growth in countries that have not yet embarked on a path of sustained modernisation.

9.4.3 Technological capability accumulation through imitation and TRIPS

The studies investigating technology development of Korea (Kim, 1997a) and Taiwan (Hobday, 1995) showed that firms in these countries began mainly as imitators, although Korean industry experience shows that this does not continue indefinitely. This research points to a similar pattern of capability development in the Indian pharmaceutical industry. The non-formal mode of imitation; reverse engineering, has played a significant role in development of basic capabilities in the Indian pharmaceutical industry.

The weak patent system allowed development of basic and intermediate process R&D capabilities and built production capabilities in the Indian pharmaceutical industry. This finding supports the observation by Kim and Nelson (2000) who suggest that duplicative imitation, if legal, is an astute strategy in the early industrialisation of low-waged, catching-up countries, as the technology involved is generally mature and readily available and duplicative imitation of mature technology is relatively easy to undertake.

However the universal adoption of strong patent protection will affect the application of imitation and reduce the opportunities for firms in developing countries to use this mode of knowledge acquisition. This certainly raises the question about strengthening of patent laws all over world, especially in developing countries irrespective of the capabilities of domestic industry. The strong patent law will affect the development of basic or intermediate capabilities in firms from developing countries.

Developing countries are not homogenous. Their scientific and technological capabilities differ widely. The findings of this research indicate that the interests of developing countries are best served by tailoring their intellectual property regimes to their particular economic and social circumstances.

9.4.4 International knowledge transfer and emerging role of diaspora

This research showed the importance of the diaspora (trans-national community of immigrated Indian scientists and engineers) and Indian scientists educated or working in advance countries as an important source of knowledge for Indian pharmaceutical firms. The crucial role of scientists or engineers studied or worked in advanced countries as a carrier of tacit knowledge is not unique to India. In extensive analysis of the "Asian miracle", the World Bank (1993) emphasises that the return of foreign educated nationals has provided significant transfer of best practises and state of the art knowledge to South Korean and Taiwanese semi conductor firms. Recent firm level studies (Kim, 1997; Song et al, 2003) have also provided anecdotal evidence of the importance of human embodied technology transfer in the learning processes of Korean and Taiwanese firms in the semi conductor industry. Similarly this research also shows that migration of educated Indians in the past to advanced countries have opened up a different strategic option for new technology sourcing for Indian firms. It provide evidence to the observation by Saxenian (2002) that trans-national communities may become as important as more commonly recognised actor – states and multiple corporation – in the growth of new centres of technology entrepreneurship.

The hiring of Indian scientists educated or working in advance countries emerged as one of the main mechanisms of knowledge acquisition which allowed Indian pharmaceutical firms to develop capabilities in innovative pharmaceutical R&D. The presence of the diaspora gave Indian firm an entry to advance technical knowledge which could have been difficult to access through other formal or informal modes of technology transfer and creates advantage for Indian industry which could have been absent. The case of brain drain is turning into brain bank and helping development of capabilities through diffusion of knowledge by reverse brain transfer. This has an important implication for international knowledge transfer as mobility of scientists across national borders and presence of diaspora can mitigate the localised nature of knowledge spill-over and can accelerate international R&D spill-over. This suggests that learning by hiring offers a mechanism to overcome obstacles in the case of technically advanced and organisationally bound technologies. It also highlights the importance of human embodied technology transfer and its role in developing capabilities of firms.

This research however strongly points out that this advantage does not overcome the issue of developing good organisational processes for delivering innovation or improvements in living and educational environments. The reverse brain drain does not take place automatically; government and firms have to create infrastructure and opportunities for them to utilise their advanced skills at home. The presence of the diaspora or migration of

scientists can help entrepreneurial firms in developing countries play a major role in technology areas as long as they know how to manage organisational knowledge and create conditions that will facilitate development of innovative capabilities. This research shows that Indian pharmaceutical firms invested in building R&D infrastructure, set up various organisational mechanisms and created international level incentive structures to tap this research talent.

This finding has further implications for research in international technology transfer and development of capabilities in developing countries. The transfer of knowledge through human mobility is not a straight forward process. For example former R&D president of Ranbaxy commented,

"it takes time for these scientists to adjust and most of them change. (But) as a company we don't have to change anything; they adjust themselves because what we have is very international structure. So we don't have to change every time a new person is coming, what we have is right structure; people have to fit into it",

while in the same firm the senior scientist hired from the US suggested that in the beginning he invested a lot of time in changing R&D culture in the firm. This clearly points out transfer or diffusion of knowledge through hiring scientists is a complex process. Therefore more research is needed to understand the firm and country level issues involved in diffusion of knowledge through linkages with the diaspora or migration of scientists and engineers.

In conclusion, findings of this research contribute towards capability development in firms from the developing countries and highlight the emerging mechanisms of knowledge acquisition in form of linkages with diaspora and migration of scientists. This study also shows that as far as intra firm learning is concerned, learning processes followed by technology frontier firms are also applicable to firms from developing countries. However, it also points out that the patterns of evolution of in organisational characteristics such as sources of technology and structure differs from the usual findings in advanced countries like the U.S. and U.K. The heterogeneous nature of developing countries economic resources and industries makes it essential to test findings of the results in different industries and countries. The change in trade rules as a result of WTO agreements also affecting the 'rules of the game' in other sectors. For example, in textile industry the 'removal quota systems' due to WTO agreements is creating turbulent environment for firms in textile exporter countries like Pakistan, India and South East Asia. Such cases offer an opportunity to test the finding of this research and develop a comprehensive model for capability development in firms from developing countries.

The emerging new mechanism of knowledge acquisition; linkages with diaspora and migration of scientific labour have implications for diffusion of scientific knowledge in developing countries. A comparative study between firms and countries needs to be done to unravel the firm and country issues involved in diffusion of knowledge through migration of scientific labour in developing countries. The brain gain thesis needs a further investigation in other contexts as well, for example examination in labour market sectors other than science and technology like managerial and professional. The findings of such research will certainly provide useful guidance for the practice and policy development in developing countries.

Thus further examination of organisational and policy issues associated with capability development in developing countries which are at different levels of development is essential in order to generalise the findings of this study and to develop a robust development theory.

9.5 Conclusion

The accumulation of technological capabilities and development of innovative R&D competencies in the Indian pharmaceutical industry provides an insight for policy makers in other developing countries. It provides the basis for understanding some of the essential elements of effective technology strategy and policy that are required for efficacious development of countries that have not yet embarked on a path of sustained modernisation. This research shows that the Indian government's import substitution industrial policies and weak patent laws provided the Indian pharmaceutical industry with a protected environment and helped Indian firms to develop basic capabilities in pharmaceutical R&D. But these measures also reduced the incentives for innovation and hampered technological growth of Indian firms. The liberalisation of industrialised policies in 1990 spurred the technological growth in industry. Thus in the case of Indian pharmaceutical industry the industrial liberalisation stimulated innovation but state interventions and protection helped industry initially when it did not have basic capabilities required to operate. The liberalisation of Indian industrial policies and growing of maturity of Indian pharmaceutical industry contributed to movement of Indian pharmaceutical firms towards innovation. However, the policy change, in the form of strengthening of patent law, created a crisis of existence for Indian pharmaceutical firms and that played an important role in accelerating movement of these firms towards the innovative R&D competencies. The ambidextrous capability development in the Indian pharmaceutical industry as a response to change in patent law has an important implication for pharmaceutical firms in other developing countries which will be facing similar challenges due to the TRIPS agreement.

The entry in the generic market of advance countries helped Indian firms to over come two sets of extreme disadvantages; dislocation from frontiers of pharmaceutical research and innovation and distance from advanced markets. The present study also revealed the important role of the diaspora (trans-national communities of Indian scientists and engineers) as a source of knowledge for Indian pharmaceutical firms.

The Indian pharmaceutical industry's development experience shows that the fast changing global economic environment is not inimical to efficacious development for firms and industries in developing countries. The forces of globalisation like WTO agreements do impose some restrictions on developing countries in terms of choice of policy selections. However as Westphal (2002) suggests globalisation and changes in technology are also removing barriers to international trade and offering new opportunities for developing countries to pursue a strategy of export led technological growth and development. For example, the development of innovative R&D capabilities in Indian pharmaceutical firms is giving rise to the new international division of labour in the pharmaceutical sector. This is opening new possibilities and economic opportunities of convergence for global as well as Indian pharmaceutical firms on pharmaceutical R&D value chain. The global pharmaceutical industry is undergoing turbulent times due to the decrease in research productivity, consumer and government pressure on firms to reduce rising healthcare cost and the increasing cost of drug discovery and development. The new division of labour and uniformation of IPR laws all over the world suggest that there are further new opportunities that can emerge in world pharmaceutical markets. The Indian pharmaceutical industry's role in reducing the healthcare cost on the basis of superior process R&D and manufacturing capabilities is already well documented. The ongoing expansion of international markets for technology and intellectual property rights may well come to serve as a force for strengthening "licensing out" rather than "licensing in" for less developed economies. The licensing agreement of molecules between Indian pharmaceutical firms and MNC pharmaceutical firms may be early steps in that direction and such licensing will strengthen Indian incentives to expand investment in R&D for pharmaceutical firms in India as well other developing countries.

Although the Indian pharmaceutical firms development of competencies in innovative product R&D are obviously modest beginnings in context of the immense world pharmaceutical industry, they show competence for high-tech R&D in which India may learn to play a prominent role, especially given the large pool of qualified scientists who are seriously underemployed. This potential convergence between Indian pharmaceutical industry and large multinational pharmaceutical firms has wider implications for access to

medicines for the large population in developing countries as well as combating rising healthcare costs in developed countries.

The ambidextrous capability development model and licensing strategy in product R&D practised by Indian pharmaceutical firms is giving rise to a new pharmaceutical R&D business model which has implications for the development of domestic pharmaceutical industries in other industrialising countries. Pharmaceutical industries in some countries like South Korea and China have also developed basic and intermediate capabilities in process R&D and manufacturing. In this context mechanisms adopted by the Indian pharmaceutical industry to develop an advance level of process and product capabilities can be applicable to further growth and development of pharmaceutical firms in those countries.

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Appendix 1

NEW DRUG DISCOVERY AND DEVELOPMENT PROCESS

Discovery Scientific research Chemistry, Biology, Pharmacology		Development Medical and Clinical testing		Marketing Post Marketing Studies
Preclinical stage Time: Avg. 18 Range: 1-3 years	IND 2-6 Months	Clinical Stage Average: 5 years 2-10 years	NDA Average: 2years 2 months-7 years	
Initial Synthesis Animal Testing Volunteers		Phase I Safety, Toxicity 50-200	Phase II Efficacy 100-1000	Phase III Effectiveness 500-5000		Adverse reaction reporting Survey sampling/ testing
Rate of drop out: 99%		70%	20%	5-8%		

Pharmaceutical new product development is divided in the two stages: A. Discovery and B. Clinical Development.

A. Discovery stage: compounds are screened for activity and promising lead molecules are selected for further developments.

1. Pre-clinical Stage

The pre-clinical stage consists of the laboratory screening of molecules to evaluate their therapeutic potential and toxicity. The drug is tested in-vitro laboratory studies followed by animal studies and reviews of related drugs along with testing of chemical stability of the drug.

2. IND: Investigational New Drug Application

IND is an investigational new drug application file by firms to conduct test of a drug on human volunteers to test safety, efficacy and effectiveness.

B. Development stage: Candidate drugs are subjected to a series of increasingly demanding screening steps that seek to demonstrate that the drugs is an improvement over current therapies and to collect evidence necessary to convince regulators and clinical users of its safety and efficacy.

1. Clinical stages

The clinical trial becomes successively more complex and demanding, beginning with small trials aimed at studying the basic behaviour of the drugs in human beings and often ending in large-scale trials in an international population of patients.

Phase I: In Phase I clinical trials safety is determined by testing of the developed drug on healthy human volunteers. This attempt to establish how human body handles the new drug and what toxic effects, if any are experienced. These trials are invariably placebo controlled and involved small number of healthy volunteers. These trials are conducted within the hospitals and volunteers are often young people, traditionally medical students.

Phase II: In phase II clinical trials efficacy at different dosage strengths is evaluated by testing the drug on patients for the first time. Once again this trial will usually conducted in hospitals but will possibly involve a few hundred patients.

Phase III: In phase III clinical trial overall efficacy (compared with existing treatments or placebo) is tested in large patients sample. This is most expensive phase of the all clinical trials. This process is conducted under careful regulatory guidelines, covering everything from scientific and ethical standards to record keeping.

NDA: New Drug Application

NDA is an application for approval of marketing the drug from drug regularity agencies. The FDA can accept or reject the application or alternatively require that the new medicine undergo further clinical test to assess more carefully its safety and effectiveness.

Post marketing studies

Once drug is approved for marketing it is kept under surveillance by the firms and the FDA. The wide spread usage may reveal the information that was not found in the clinical trials. In case of unanticipated side effects. FDA forces companies to add warnings on the

package. If the level of side – effects or toxicity is severe then the, FDA can even withdraw the product.

The entire drug development cycle can take anywhere from 8 to 12 years from the time a compound is discovered until it is approved for sale. The drop out rates goes on decreasing from pre clinical to phase III trials. Starting with as high as 99% in pre clinical to 70% in phase I, 20% in phase II and 5-8% in phase III. The average time from initial synthesis to NDA approval is approximately 100 months where pre-clinical takes on average 18 months, clinical phase takes on an average 5 years while NDA review takes up on an average 2 years

Appendix II

Glossary of terms

ANDA: Abbreviated New drug application

API: Active Pharmaceutical ingredient

CDRI: Central Drug Research Institute

CIPR: Commission on Intellectual Property Rights, UK

CSIR: Council for Scientific and Industrial Research

DMF: Drug Master File

DPCO: Drug Price Control Order

EMR: Exclusive Marketing Rights

GCP: Good Clinical Practises

GLP: Good Laboratory Practices

GMP: Good Manufacturing Practices

GATT: General Agreement on Trade and Tariffs

Generic drugs: Off-patent drugs, which have received market approval based on proof of bioequivalence to the originator's product.

IPR: Intellectual Property Rights

NCE: New Chemical Entity

NCL: National Chemical Laboratory

NDDS: New Drug Delivery Systems

NPIL: Nicholas Piramal India Limited

TRIPS: Trade Related Intellectual Property Rights Organisation

W.T.O: World Trade Organisation

Medical Terms

Antiulcerant: Class of drugs against peptic ulcers

Anti-infective: Something capable of acting against infection, by inhibiting the spread of an infectious agent or by killing the infectious agent outright.

Anti-inflammatory: a drug that reduces inflammation and the redness, heat, swelling, and increased blood flow that accompanies it; inflammation can be caused by injuries, infections, and many chronic diseases such as rheumatoid arthritis.

Anti diabetic: Class of drugs that help body to utilise insulin more effectively.

Anti obesity: class of drugs that increase energy expenditure and weight loss by neural and chemical regulation

Anti oxidants: Nutrients found naturally in the body and in plants such as fruits and vegetables

Anti-psoriasis: Class of drugs used to treat a common chronic, skin disease marked by exacerbations and remissions.

Anti-migraine: class of drugs used to treat a periodic attacks of headache, commonly associated with irritability, nausea, vomiting, constipation or diarrhoea .

Cardiovascular: Branch of medicine concerned with the circulatory system of the heart and blood vessels

Hepatotoxicity: Liver damage caused by medicines and other chemicals

Pharmacogenomics: The study of how an individual's genetic inheritance affects the body's response to drugs

Respiratory: Branch of medicine concerned with the respiration diseases.

Rheumatology: Treatment and care of rheumatism and arthritis

Urology: Branch of medicine concerned with the urinary tract in males and females and with the genital tract and reproductive system of males.

Appendix III

List of interviews

First Phase

1. Dr. D.Sivaram: Director, National Chemical Laboratory, Pune
2. Dr. Raj Hirwani: Business Development Manager, National Chemical Laboratory, Pune
3. Dr. Prabudtha Ganguli: Patent Expert, Consultant Vision-IPR group, Legal advisor OPPI (Organisation of Pharmaceutical Producers of India)
4. Mr. Francis P.K.: Editor, Pharmabiz
5. Mr. Ananth Iyer: Assistant Editor, Express Pharma Pulse
6. Dr. Gopakumar Nair: IPR consultant, President of IDMA(Indian Drug Manufacturers Association)
7. Dr. Himadri Sen: President, Pharmaceutical Research and Regularity affairs, Lupin laboratories ltd
8. Ms. Sophia Mumtaz: Assistant Director, Intellectual property management group, Lupin laboratories ltd
9. Mr. Dilip Shah: Consultant, Vision–India consulting, Secretary of I.P.A. (Indian Pharmaceutical Association)
10. Dr. M.K. Nair : Consultant

Second Phase

List of persons interviewed:

a. National Chemical Laboratory (Pune)

1. Dr. M.G. Kulkarni – Head, Polymer Science Engineering and NDDS

b. Dr.Reddy's Laboratories (Hyderabad)

2. Dr. Venkatswarlu – Former R&D president and Board Member
3. Dr. Rajgopalan – President, Discovery Research

c. Ranbaxy Laboratories ltd (Delhi, Gurgaon)

4. Dr. Jag mohan Khanna- Former R&D director and Board Member
5. Dr. Bimal Raizada – Vice – President
6. Dr. Dilip Upadhyay – Associate Director, Microbiology, New drug discovery research
7. Dr. Rita Sarin – Group Leader, Intellectual property

8. Mr. Sugata Bhattacharya: Head, Europe Operations

d. Glenmark (New Mumbai)

9. Mr. Sameer Paigankar – Director, Strategic Planning

10. Dr. B. Gopalan – Sr. Vice President (Chemical research)

e. Nicholas Piramal (Mumbai)

11. Dr. Swati Piramal – Director, Strategic alliances and communications

12. Dr. Bansi Lal – Director, Quest institute of life sciences (Nicholas Piramal R&D) 13.

Dr. Swati Baltembe –General Manager, Medicinal Chemistry and Analytics;

Head, Patents department

f. Wockhardt (Mumbai, Aurangabad)

14. Dr. Noel De Souza – Director, R&D (No recording)

15. Dr. Mahesh Patel – Director, Anti infective research

16. Dr. Sahib- Director, Genomics & biotechnology

17. Dr. Shukla – Director, Informatics Group

18. Dr. Yati Chugh - Head, Pharmacology division

19. Mr. V. Rajan – Managin Director, Wallis laboratories (UK Operations)

g. Lupin Laboratories Ltd (Pune)

20. Dr. B.N.Roy – Director, R&D

21. Dr. Himadri Sen – President, Pharma Research and Regulatory affairs.

22. Dr. Sudershan Arora – President, New Chemical entities Research

h. Ernst and Young (Hyderabad)

23. Mr. Amit Dutta – Analyst Biotechnology

Email correspondent

1. Dr. Mukund Chorghade

President and Chief Scientific Officer

Pharmaceutical Sciences Division

D & O Pharmachem, Inc., USA

2. Dr. Hemant Joshi

Senior Scientist,

Barr Laboratories, USA

3. Mr. Mahdeep Saran

Clinical Research Officer

Almebic Laboratories ltd, India

4. Dr Aakash Ganju, MD

Medical Advisor,

Pfizer Global Research and Development

India

5. Dr. Pankaj Shah

Bristol Mayer Squibb

USA.

Appendix IV

Interview Question Bank

A. TRIPS and its effects -

1. What is your opinion about changes in patent law and its effect on R&D activities in Indian pharmaceutical industry? What important trends are emerging in Indian pharmaceutical industry and how they are affecting your organisation?

2. What do you think is the main challenge before Indian firms particularly preparing for 2010 or 2015 scenarios?

B. Firm specific:

3. How would you describe the R&D philosophy of your company? What is the overall role of the R&D in your organisation compared to production and marketing?

4. How much is your organisation focused on product R&D or innovative R&D?

5. When did your company decide to start work on innovative R&D?

6. What were the main challenges/ difficulties before company when you started working on innovative R&D? What were the major constraints before transformation?

7. How difficult is it to transform from being cost commodity skill driven player to being innovation driven players? Organisation-wise, what have been the challenges for your company?

8. How has your company overcome these issues? What strategies has your company employed to over come those difficulties?

C. Absorptive capacity

9. How much knowledge accumulated in process R&D is relevant in product R&D?

10. The Indian firms are steadily increasing the investments in their R&D over the years. In your opinion what is the thinking behind that?

10b) In general terms where is this investment going i.e. on infrastructure development or man power and specifically is it moving towards innovative R&D?

11. You have chosen some specific fields for new drug discovery research. What was the thinking behind choosing those fields? Were those areas decided by the market demand or available knowledge in that therapeutic class available within the firm?

D. Acquisition of capabilities:

12. The innovative output in terms of NDDS and NDDR from your R&D laboratories is very impressive compared to other Indian firms. What are the reasons behind the success of your company?

13. How has your company acquired the capabilities in NDDS and NDDR?

14. How difficult it is to attract the research talent from abroad?

15. What changes has the organisation made or needs to make for attracting top talent?

16. Is this the only solution? Have you tried other ways of acquiring the knowledge in innovative R&D?

17. In the new drug discovery and development research has become IT intensive and tools like bioinformatics, high throughput screening and combinatorial chemistry plays important role. Is your company focussing on any of these fields?

18. If yes then how is your company building infrastructure required for innovative R&D?

D2. Collaborations and Networking:

19. In innovative R&D what are the areas generally pursued through alliances?

20. What are companies really looking to gain through networking?

21. What were the gains of those collaborations?

22. What efforts has your company made to promote networking and collaboration between the organisations? Is there any individual or department whose primary function is look into the opportunities?

23. If yes, when this activity or department started in the company?

24. Does nature of work in collaborations with Indian research institutes differ from those of overseas institutes? If yes then can you describe how it differs?

D3. Scanning of Technological information

25. What sources of information do you used to get latest technological advances or commercial opportunities?

26. Lot of technological advances around the area of new drug discovery are happening around the world. So how does the company keeps in touch with those advances?

Up-gradation of capabilities

27. What mechanisms company has put to facilitate the knowledge up-gradation of the scientist?

28. Does formal training programme have any role channelling the knowledge of scientist towards the innovative R&D? or it is mostly learned by working on the experiments?

Integration or combination of knowledge

29. The areas of NCE and NDDS development require the expertise in various disciplinary areas and their effective coordination and integration. How is your company trying to achieve this?

Organisational structure:

30. Has your company made any structural changes to its R&D to facilitate working on innovative R&D? If yes, what structural changes it made to its R&D?

Resource allocation:

31. How is it determined who works on which project? How resources are assigned to projects? Was it done same way as reverse engineering R&D?

Cross disciplinary teams:

32. Does separate multi disciplinary teams works on innovative projects? How do these teams come into existence? Are they cross-disciplinary in nature?

33. Does same team work with project till its final completion? Or different teams work on the different phases?

Review of research

34. How the project is coordinated and supervised? Does these teams reports to same manager? Is same techniques are applied in reverse engineering research projects?

35. How the review of the project is done? Does it involves measures like peer reviews?

IPR

1. According to you what are the key capabilities for the IPR management?

2. What is the company doing to build capabilities in key IPR functions like infringement analysis, patent search and patent claim drafting?

4. How did you achieve competence in getting regularity approval specifically in developed markets?

5. How would you describe your firm's patenting strategy?

Appendix V

Survey Questionnaire

The Open University
Business School
Walton Hall
Milton Keynes
MK7 6AA

Telephone +44 (0) 1908 652884
Fax +44 (0) 1908 655898
http://oubs.open.ac.uk

Survey –

This survey is aimed at exploring the effect of change in patent law on Indian pharmaceutical industry focusing on R&D activities within it. In survey the term innovative R&D is used for the R&D activities involved in research of new drug delivery systems or new chemical entities or analogue research.

Please answer the questions by ticking (√) on your choice.
N = not applicable

Do you wish to receive the results from the survey?

YES	NO

Name -

	Strongly agree				Disagree completely	
1. Effect of change in patent law on Indian pharmaceutical industry						
• The change in patent law **will completely stop** reverse engineering of patented molecules within R&D of Indian pharmaceutical firms.....	1	2	3	4	5	N
• The change in patent law **will restrict but not end the** reverse engineering within R&D of Indian pharmaceutical firms.....	1	2	3	4	5	N
• The change in patent law **will have no effect on** reverse engineering activity within R&D of Indian pharmaceutical firms.....	1	2	3	4	5	N

2. Major constraints

• **Lack of R&D manpower skilled in product research** is the constraint

for pharmaceutical industry in pursuing innovative R&D..... 1 2 3 4 5 N

• **Lack of IPR trained manpower like patent attorneys** is the constraint for pharmaceutical industry in pursuing innovative R&D..... .... 1 2 3 4 5 N

• **Lack of financial resources** is the constraint for pharmaceutical industry in pursuing innovative R&D..... ....1 2 3 4 5 N

• **Lack of infrastructure required for innovative R&D** is the main constraint for pharmaceutical industry in pursuing innovative R&D..... 1 2 3 4 5 N

• **Lack of good research institutes or universities** is main constraint for pharmaceutical industry in pursuing innovative R&D..... ....1 2 3 4 5 N

3. Relevance of accumulated knowledge through reverse engineering in innovative R&D

• The accumulated knowledge in reverse engineering **will greatly contribute** in innovative R&D activities..... .....1 2 3 4 5 N

• The accumulated knowledge in reverse engineering **will act only as a base and not directly relevant** for innovative R&D.....1 2 3 4 5 N

4. Difference of Knowledge base required in reverse engineering R&D and innovative R&D

• The activities in reverse engineering R&D requires the combination of knowledge from **organic, medicinal chemistry and pharmacology** ..... 1 2 3 4 5 N

• The activities in innovative R&D requires the combination of knowledge from **chemistry, biology as well as formulation and toxicology**. .....1 2 3 4 5 N

5. Reduction of entry barriers:

• Technological advances like high-throughput screening, combinatorial chemistry and bioinformatics have transformed the drug discovery and development process..... 1 2 3 4 5 N

• Technological advances like high-throughput screening, combinatorial chemistry and bioinformatics have demystified the drug discovery and development process offering the opportunities to pharmaceutical firms from emerging countries..... 1 2 3 4 5 N

6. Pharmaceutical R&D

• In pharmaceutical R&D, scientist with experience in process R&D can easily learn knowledge in innovative or product R&D by studying the complete set of blue prints.....1 2 3 4 5 N

• In pharmaceutical R&D, scientist with experience in process R&D can easily learn knowledge in innovative or product R&D by talking to experienced R&D personnel.....1 2 3 4 5 N

- In pharmaceutical R&D, educating and training R&D personnel in innovative R&D is an easy job.....1 2 3 4 5 N

- For product R&D, knowledge about many different disciplines needs to be combined.....1 2 3 4 5 N

- Successful filing of the generic patents in US market indicates high level of regulatory competence.....1 2 3 4 5 N

7. Capability of research institutes and universities in India

- The linkages between academia, research institutes and Indian pharmaceutical industry are very weak..... .1 2 3 4 5 N

- The Indian pharmaceutical industry and research institutes have strong capability in chemistry and other related disciplines.....1 2 3 4 5 N

- The Indian pharmaceutical industry and research institutes have weak capability in biology and other related disciplines.....1 2 3 4 5 N

8. Indian firms approaches:

- Indian firms are hiring scientists from overseas RI, universities or MNC R&D labs to acquire the knowledge in innovative R&D.....1 2 3 4 5 N

- Indian firms are acquiring regulatory competence by filing patents in different countries.....1 2 3 4 5 N

- Indian firms are acquiring regulatory competence by hiring IPR consultants from abroad.....1 2 3 4 5 N

9. Please indicate the degree and direction of change in value / importance of the following areas for Indian pharmaceutical industry (between 1995-2003).

	Very strong increase		stay same		Very strong decrease	
• The value of reverse engineering projects in over all R&D projects.....	1	2	3	4	5	N
• The promotion of scientist linked to publications	1	2	3	4	5	N
• The importance of medicinal chemistry	1	2	3	4	5	N
• The importance of genomics.....	1	2	3	4	5	N
• The importance of alliances with other firms to access knowledge of areas						
a. archival libraries.....	1	2	3	4	5	N
b. as other sources of natural compounds.....	1	2	3	4	5	N
c. combinatorial chemistry libraries.....	1	2	3	4	5	N
d. lead generation.....	1	2	3	4	5	N
e. lead optimisation.....	1	2	3	4	5	N
f. screening of the molecules.....	1	2	3	4	5	N

h. clinical research.....1 2 3 4 5 N

10. Indian firms have in-house capability to do the following processes in innovative R&D

	Strong		moderate		Lack
A. Basic genome research					
• Gene expression	1	2	3	4	5 N
• Gene targeting	1	2	3	4	5 N
B. Identification of target molecule					
• High throughput screening	1	2	3	4	5 N
• Combinatorial method	1	2	3	4	5 N
C. Clinical Scrutiny of leads					
• Toxicology study capabilities	1	2	3	4	5 N
• Phase I	1	2	3	4	5 N
• Phase II	1	2	3	4	5 N
• Phase III	1	2	3	4	5 N
• Regularity competence to file NDA patents in developed markets	1	2	3	4	5 N

Any other:

11. According to you which Indian firms are successful in innovative R&D?

1. 4.
2. 5.
3. 6.

12. Any comments you want to add: